

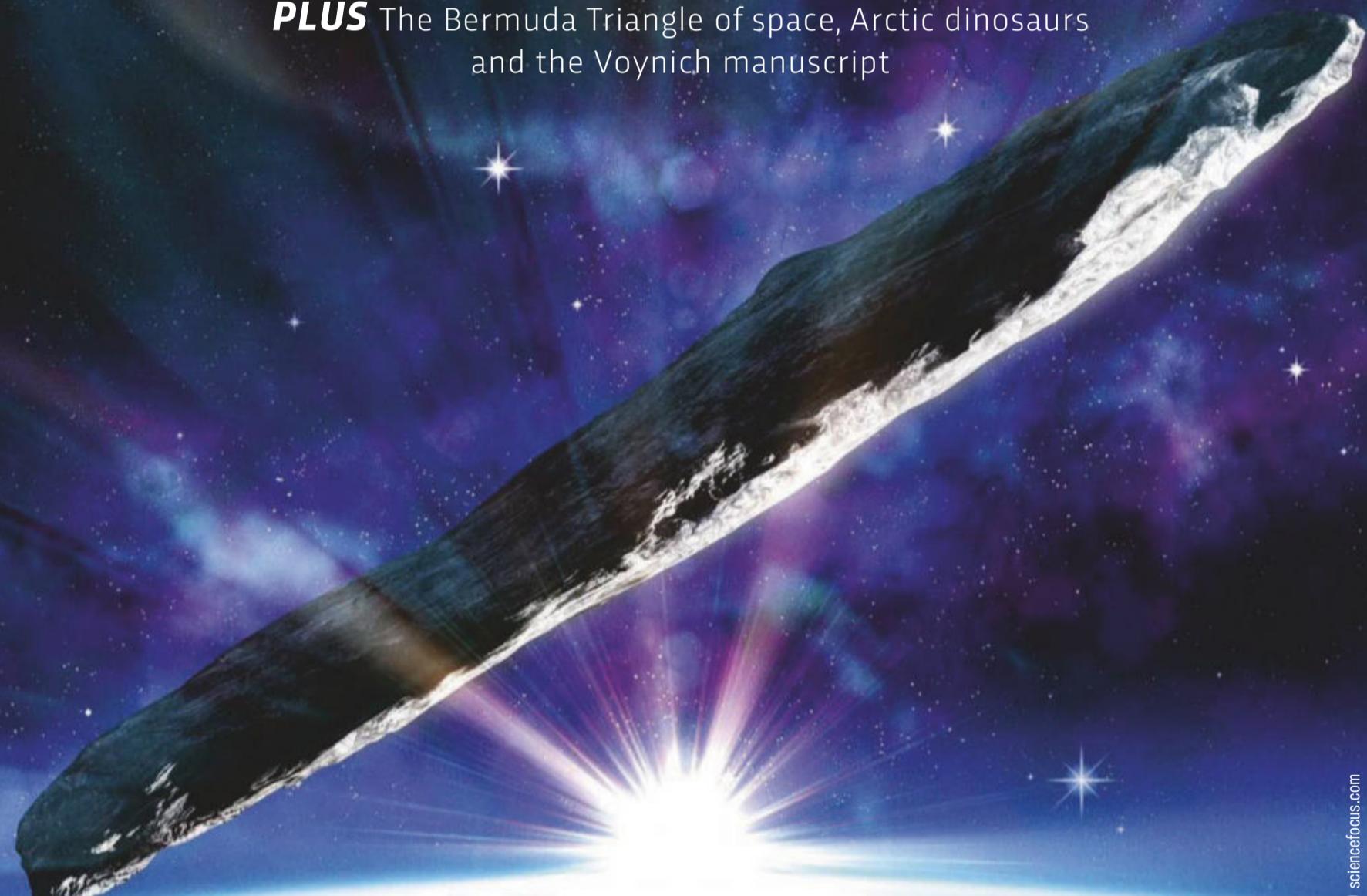
FOCUS

SCIENCE | TECHNOLOGY | HEALTH

THE MOST MYSTERIOUS OBJECTS IN THE UNIVERSE

**How we'll decipher the secrets of 'Oumuamua,
Galaxy X and Planet Nine**

PLUS The Bermuda Triangle of space, Arctic dinosaurs
and the Voynich manuscript



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New tech that spots coronary disease before it happens

QUANTUM WEIRDNESS

How a living thing can be in two places at once

MY BRAIN MADE ME DO IT

Understanding the link between head injuries and criminal behaviour

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An **ingested Lego head** takes one to three days to see daylight again →p23

WELCOME



The Universe is strange. I sometimes think that could be *BBC Focus*'s motto, since I seem to learn something inherently weird every issue. It's what makes this magazine, and working on it, so much fun.

For example, this month I learned there's a patch of the International Space Station's orbit that astronauts describe as the Bermuda Triangle of space. It's a spot above the Earth where the space station's instruments and computers fail and the astronauts hallucinate flashes of light. Find out what causes this and other space oddities on p40.

I also discovered *Formica archboldi*, an ant that leaves the severed heads of its considerably larger enemies lying around its nest. The heads, and their contents, are probably collected as a snack and not as some creepy hunting lodge decor. But what's puzzled scientists is how exactly *F. archboldi* ants manage to take down their bigger, stronger victims. Find out more on p16.

Or if you want the ultimate in weirdness, then there's quantum physics. Usually limited to the realm of the impossibly small, now scientists are beginning to test the scale at which these bizarre phenomena persist. As it turns out, quantum weirdness can apply to living things... p60.

Enjoy the issue, and all the bizarre stuff in it!

Daniel Bennett

Daniel Bennett, Editor

IN THIS ISSUE



BRIAN CLEGG

Science writer Brian meets the researchers aiming to prove Erwin Schrödinger and his thought experiment involving a cat – wrong. → p40



LINDA GEDDES

It turns out that some people can turn to criminal behaviour after suffering a brain injury. Freelance science journalist Linda finds out more. → p74



JAMIE MILLAR

Health writer Jamie reveals that HIIT training can help you shed kilos, build muscle, vastly improve your fitness and even boost your brain. → p67

WHAT WE'VE FOUND OUT THIS MONTH

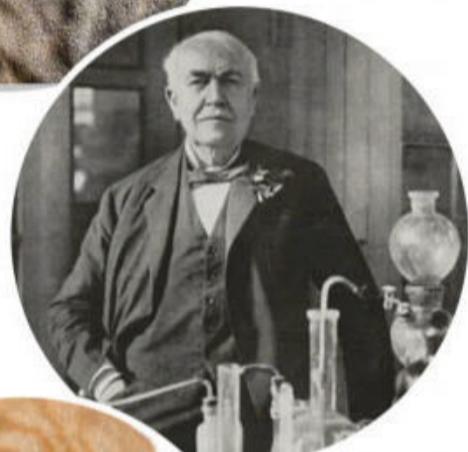
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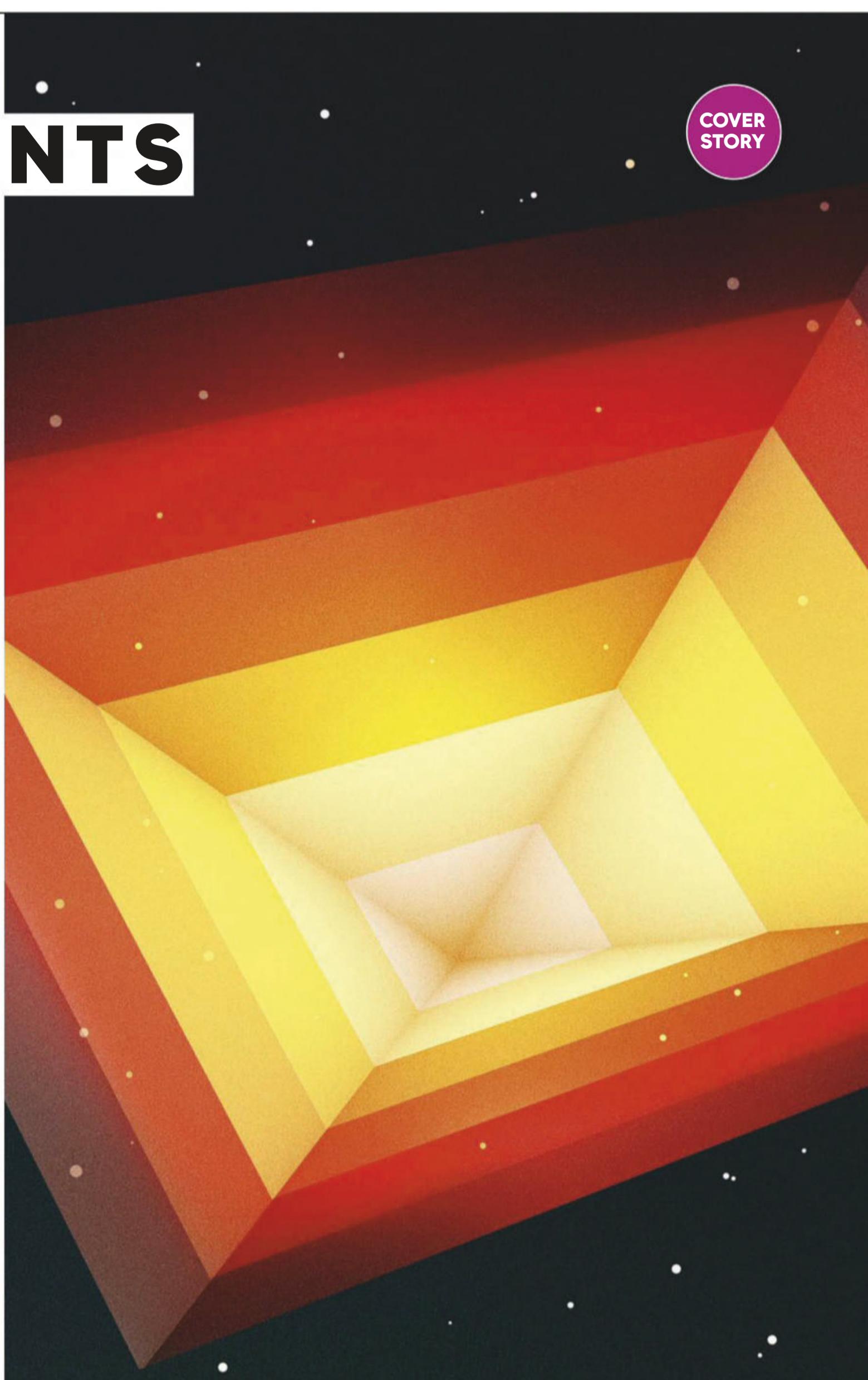
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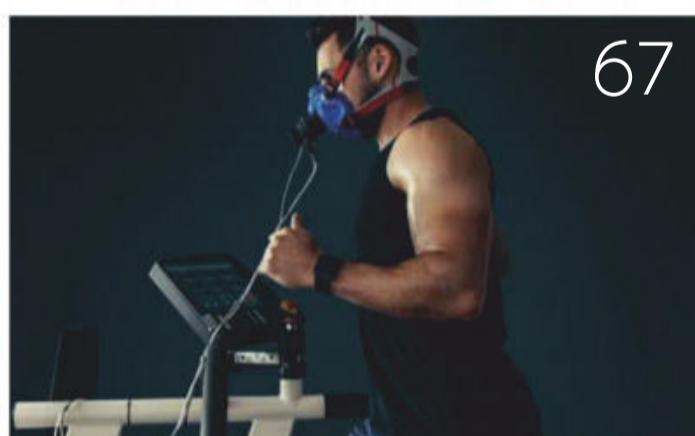
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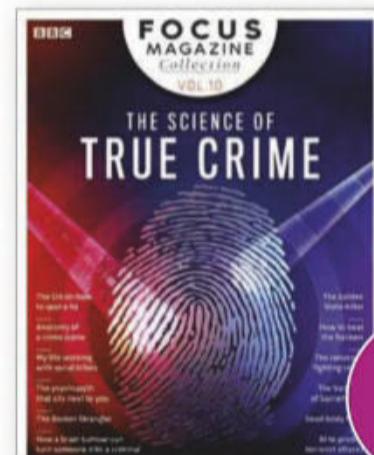
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Can't wait until next month to get your fix of science and tech? The Science Focus website is packed with news, articles and Q&As to keep your brain satisfied. sciencefocus.com



SPECIAL ISSUE



ON
SALE
NOW

THE SCIENCE OF TRUE CRIME

In this special edition from *BBC Focus*, we investigate the science that will help catch criminals, take a look at the psychology of psychopaths, and find out how crime scene investigation works (it's not like it is on telly). buysubscriptions.com/focuscollection

EYE OPENER

Tangled web

LAKE VISTONIDA, GREECE

Arachnophobes, look away. Hidden within this mass of cobwebs are hundreds of thousands of spiders, building a fortress on the banks of Lake Vistonida in northeast Greece.

Photographed last October, the 1km-long web was the handiwork of *Tetragnatha* spiders. These arachnids, also known as 'stretch spiders' because of their elongated body shape, often build their webs in long vegetation near water.

"During breeding season, the spiders produce these webs to protect themselves from predators, such as birds, small reptiles and mammals, as they mate and the females lay eggs," says Prof Adam Hart, an entomologist at the University of Gloucestershire. "The influx of spiders this year was due to an unusually warm, wet summer, which caused an increase in gnats and other small flying insects that the spiders feed on. When conditions are right, these spiders can thrive."

REUTERS





EYE OPENER

CIMON says

INTERNATIONAL SPACE STATION, LOW EARTH ORBIT

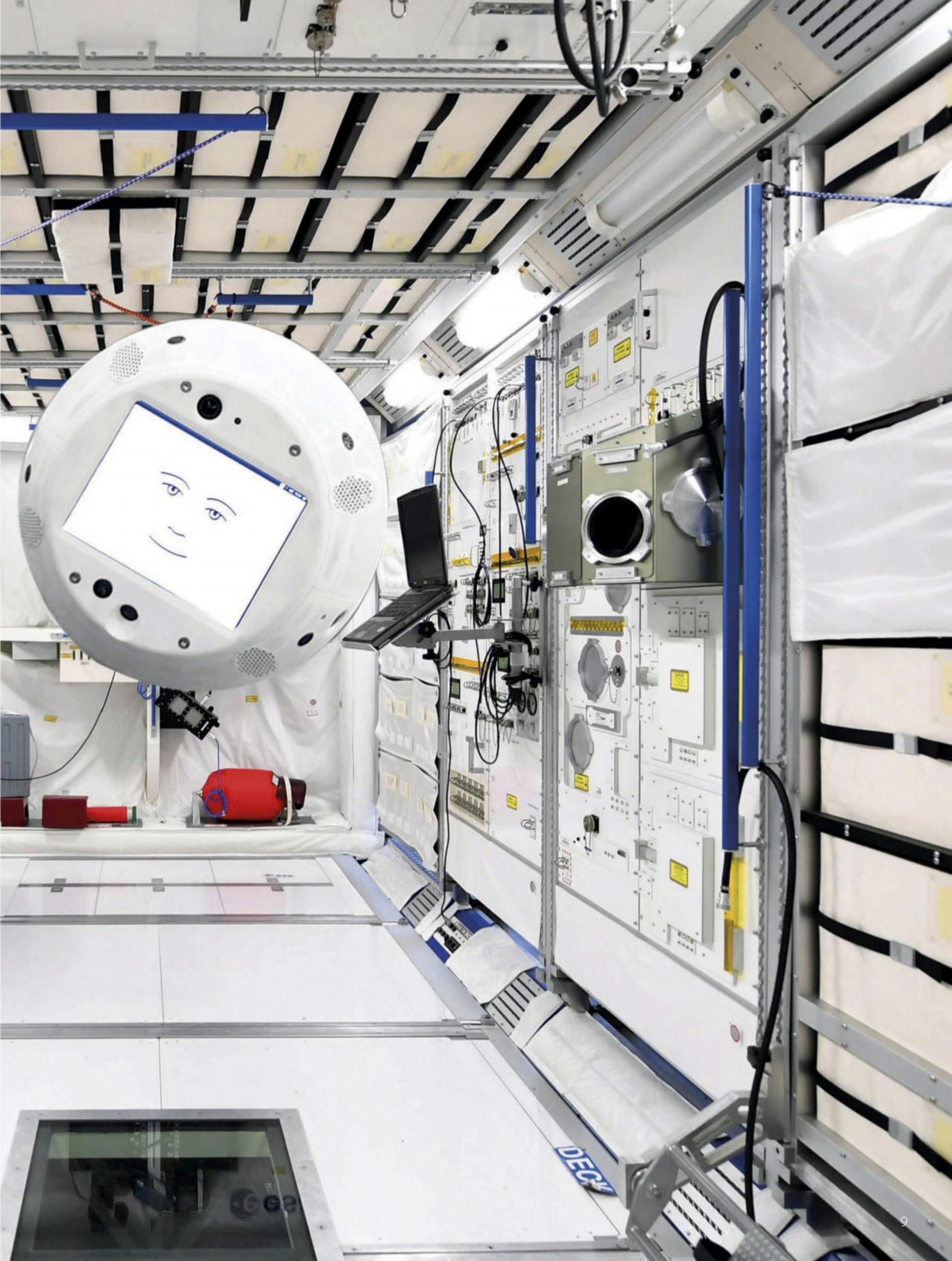
Astronauts on board the International Space Station (ISS) now have a new companion: a floating robotic head named CIMON.

Short for 'Crew Interactive MOBILE CompanioN', the spherical robot arrived at the ISS last July, and had its first interactions with Alexander Gerst – the German astronaut it'll be working with – in November.

CIMON was manufactured by Airbus for the German space agency. The robot sports a display screen, an AI 'brain' based on IBM's Watson technology, seven cameras for monitoring its surroundings and recognising faces, nine microphones for listening to voices and identifying directions, a loudspeaker 'mouth', and 12 internal fans for manoeuvring in microgravity.

CIMON is designed to assist astronauts with their work by displaying and explaining information about procedures and repairs, as well as acting as a mobile camera to find objects and record experiments. He's the first AI robot in space, but don't worry – CIMON won't be doing a 'HAL' and going rogue any time soon. The robot isn't equipped with self-learning capabilities, so it relies on instructions from its astronaut minders.





REPLY

Your opinions on science, technology and *BBC Focus*

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MESSAGE OF THE MONTH

The hope for same-sex mice-birth breakthrough

I enjoyed your news story about healthy mice born from same-sex parents (December, p19). Others may disagree but I feel this is great research. I know the technique is years away from being adapted for humans but, as a bisexual, I love the idea that should I want a child with another woman, we could have one that carries both of our genes.

To learn more about the science behind the technique, I read other articles about it and was surprised by the strong opposition shown towards this research. Comments posted online indicated that some people found it to be unethical or against God. It struck me that similar arguments were used in the 1970s regarding test-tube babies. But today we take IVF for granted as an option for couples who are unable to conceive without medical assistance.

I hope this research continues so that one day same-sex couples can have biological children.

Julie Gibson, Co Durham

➔ It is an amazing breakthrough, Julie, you're right. But, as the story points out, there are practical and ethical issues that need to be addressed before the technique can be considered for humans. Nevertheless, it's disheartening to see some of the reactions to the news, when, at this point at least, it seems the scientists are just trying to see what's possible and what they can learn from the process. No one can really predict what, if any, applications will come out of it. – **Daniel Bennett, editor**

WRITE IN AND WIN!

The writer of next issue's *Message Of The Month* wins an **STK X2**, the most advanced device to date from the British mobile manufacturer. Running on Android 8.1 Oreo with a super fast processor, the X2 is jammed packed with features to take on the big guns. Expect fingerprint technology and an outstanding 16MP camera. stklife.com



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How long before the children of same-sex partnerships share genetic material from both parents?

What about us older kids?!

I was horrified to see that in the Q&A section of your Christmas issue you had calculated the number of Santa's deliveries based on there being 200 to 700 million 'children'. What about the grown-ups? Santa delivers presents to people of all ages in my house, and I hope that he does the same for every household! I trust that you'll issue an apology to all the adults who were worried that they would miss out this year.

Admittedly, next year may be a different proposition altogether, depending on what access Santa has to



Santa has physics-defying delivery capabilities

Britain after Brexit, so we'll see!
Steve Barnet, Stirling

➔ Good point, Steve. And our most heartfelt apologies to everyone over the age of 18 whose belief in the magic of Christmas was shaken by the criteria used in our calculations. In our defence, we couldn't settle on a number that we thought gave a fair representation of all the grown-ups that could be classified as naughty and would therefore be bypassed by Santa. So we ruled adults out entirely.

– **Daniel Bennett, editor**

Calorie counter
Anthony Warner's piece on diets being counterproductive (Christmas issue, p54) interested

me, for several reasons. I spent many years being significantly overweight and it was something I struggled to remedy. I'm every bit as cynical as Anthony, when it comes to 'fad diets', the nutritionists/celebrities who peddle them, and the ill-directed motivation that comes from the desire to conform. But I take issue with the implication that it's pointless to put yourself through the misery of calorie counting because your body shape will always be dictated by your genes. It's a gross oversimplification.

I managed to lose a lot of weight over a long period, and I'm still working on keeping it off. The secret? It's as simple as eating less and exercising more. There are no miracles, no easy options and no short cuts to it. You simply have to want to do it for you (not because you feel you should); plan and follow an exercise programme that you can stick to over the long term; and count the calories in your food. I contend that the last point is essential – it is for me, at least. The capacity for different foods to fill you up is not proportional to their calorific content, so it's necessary for me to count them to ensure that I don't delude myself.

Losing weight: it all comes down to calories in vs calories out... and your genes



I genuinely believe that by doing these three things, anyone can lose weight and keep it off. By all means be cynical about fad diets. But the piece in question seemed to me to lose sight of the massive benefits to our health and well-being that come from being in better shape.

Simon Bartlett, via email

→ Fair point Simon. But no-one said losing weight was impossible, just that biology and society have stacked the odds heavily against you.

– **Daniel Bennett, editor**

In praise of... us

I wanted to say how much I enjoy the magazine. It is unfailingly fascinating. *BBC Focus* is doing a great job in bringing science to us interested non-specialists.

Mary Colwell, via email

Oops...

Dr David L Clements, of Imperial College London, has alerted us to an error on p95 of the Christmas issue. In the caption to the picture of the Very Large Telescope, we describe it as the European Space Agency's device. The VLT is, in fact, owned and operated by the European Southern Observatory.

BBC Focus

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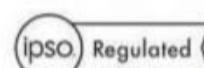
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JANUARY 2019

EDITED BY JASON GOODYER



PALAEONTOLOGY

TREASURE TROVE OF DINOSAUR FOOTPRINTS DISCOVERED IN SOUTHERN ENGLAND

Almost 100 well-preserved dinosaur footprints found on the Hastings coast

GETTY

Researchers from the University of Cambridge have identified an area of fossilised dinosaur footprints. Discovered on a section of coastal erosion along cliffs near Hastings, East Sussex, the prints are the most diverse and detailed ever found in the UK.

The footprints date from the Early Cretaceous, which stretches from 101 to 145 million years ago. There are prints from *Iguanodon*, *Ankylosaurus*, a species of stegosaur, possible sauropods (the large leaf-eating group of dinosaurs that includes *Diplodocus*), and theropods (the group of meat-eating dinosaurs that includes *Velociraptor*).

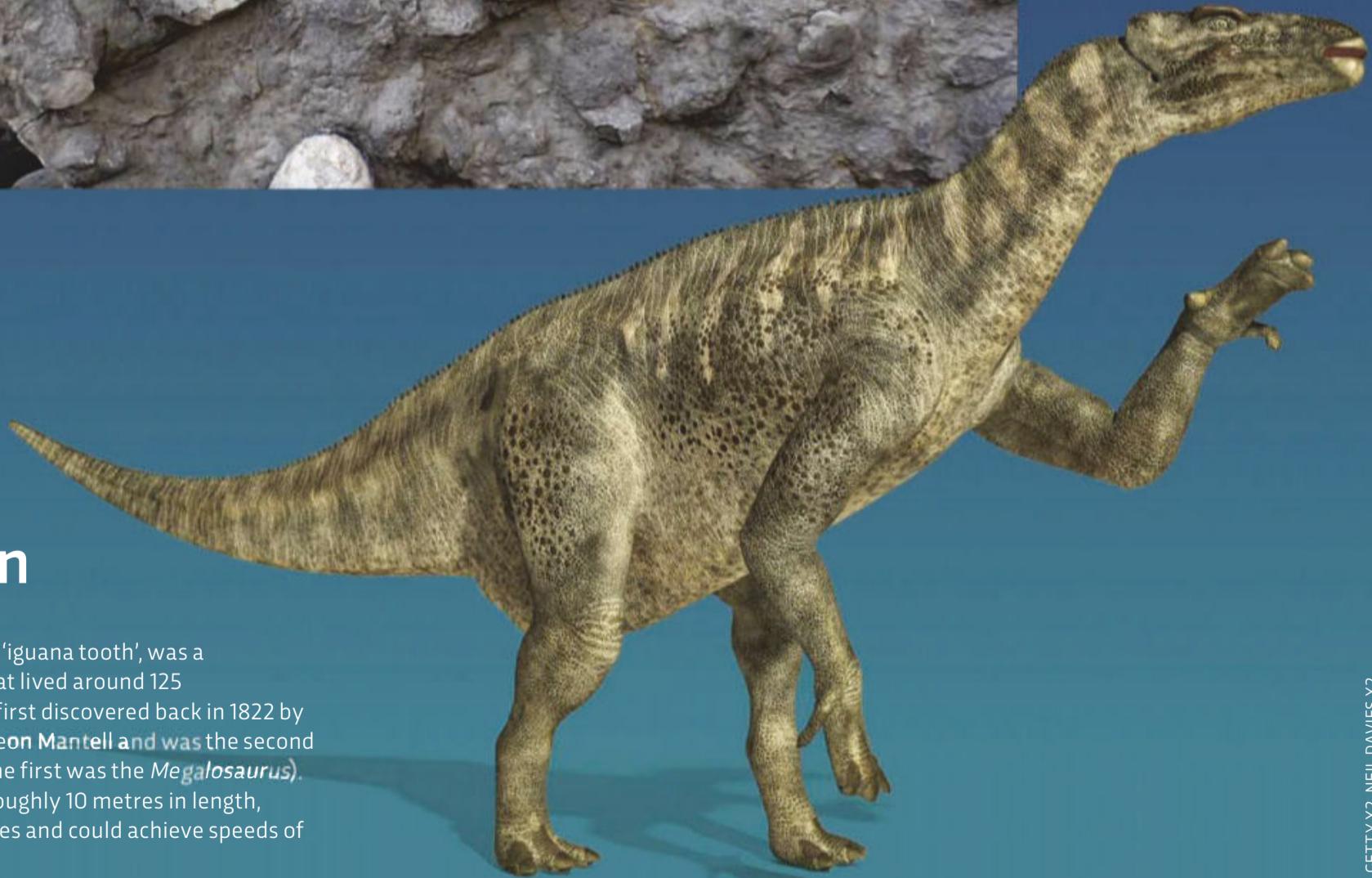
“SOME ARE SO BEAUTIFULLY PRESERVED THAT THE DETAILS OF THE DINOSAURS’ SKIN, SCALES AND CLAWS ARE VISIBLE”

“Whole body fossils of dinosaurs are incredibly rare,” said PhD student Anthony Shillito, who took part in the research. “Usually you only get small pieces, which don’t tell you a lot about how that dinosaur may have lived. A collection of footprints like this helps you fill in some of the gaps and infer things about which dinosaurs were living in the same place at the same time.”

The area around Hastings is one of the richest sources of dinosaur fossils in the UK. The first known *Iguanodon* fossil was found in the area back in 1825, and the first confirmed example of



LEFT:
Iguanodon
footprints



Iguanodon

The *Iguanodon*, meaning ‘iguana tooth’, was a plant-eating dinosaur that lived around 125 million years ago. It was first discovered back in 1822 by the English geologist Gideon Mantell and was the second dinosaur to be named (the first was the *Megalosaurus*). *Iguanodon* could reach roughly 10 metres in length, weighed around 3.5 tonnes and could achieve speeds of up to 24km/h (15mph).

fossilised dinosaur brain tissue was uncovered in 2016.

The prints range in size from less than 2cm to more than 60cm across. Some are so beautifully preserved that the intricate details of the dinosaurs' skin, scales and claws are easily visible.

"You can get some idea about which dinosaurs made them from the shape of the footprints – comparing them with what we know about dinosaur feet from other fossils lets you identify the important similarities," said Shillito. "When you also look at

footprints from other locations you can start to piece together which species were the key players."

It's likely that the site was once a water source as a number of fossilised plants and invertebrates were also found in the immediate area. The wet ground would also have helped to capture and preserve the footprints.

It's possible that there are many more dinosaur footprints hidden within the eroding sandstone cliffs found on the coast of East Sussex, but sea defences recently built in the area may make them difficult to find.

RIGHT:
Ankylosaurus
footprint



Ankylosaurus

The *Ankylosaurus*, meaning 'fused lizard', was a plant-eating dinosaur that lived around 65 million years ago. It reached about nine metres in length, weighed around six tonnes, and was covered in distinctive body armour. It had a large club-like structure on the end of its tail that it possibly used to strike other dinosaurs when defending itself.

MYSTERY OF 'HEADHUNTING' ANTS SOLVED

In the late 1950s, researchers in Florida made a macabre and perplexing discovery: ants known as *Formica archboldi* were decking out their nests with the severed heads of much larger and more aggressive trap-jaw ants. Ever since the discovery, the bizarre behaviour has puzzled entomologists – just how are the ants capable of it?

Now, by observing the ants with high-speed cameras placed in their nests, researchers at North Carolina State University think that they have the answer. *F. archboldi* are able to 'disguise' themselves as trap-jaw ants, as the cocktail of waxy substances that coats their bodies is chemically similar to that of two species of trap-jaw ant. This means they can then approach their prey unnoticed before paralysing them by spraying them with a concentrated burst of formic acid – a behaviour usually only seen when the ants are defending themselves. *F. archboldi* then finish the job with

their powerful jaws before dragging the corpses of the trap-jaw ants into their nests and systematically dismembering them.

"This was a study that grew out of reading a peculiar observation in a 60-year-old research paper. Odds were that these ant heads weren't in *Formica* nests by chance and that there was some interesting biology behind this natural history note," said Prof Adrian Smith, the head of North Carolina State University's evolutionary biology and behaviour research lab.

"The scientifically surprising finding of this study was that these ants chemically match or mimic the chemical profiles of two species of trap-jaw ant. It's really unusual for an ant species to display this much variation in chemical signature. Also, chemical mimicry is usually a tactic used by social parasites, but there's no evidence that *F. archboldi* are a parasitic species," Smith added.

Trophy hunter:
the *Formica archboldi* ant
decorates
its nests with
the severed
heads of the
bigger, nastier
prey it kills



ADRIAN SMITH, MIT CSAIL

IN NUMBERS

96

The percentage of all marine life that perished 252 million years ago in a catastrophic climate change event dubbed 'The Great Dying'. A rise in global temperature of around 10°C led to oceans losing 80 per cent of their oxygen.

90
METRES
PER SECOND

The top speed that a Dracula ant can snap its mandibles together, as measured by a team at the University of Illinois. That's the fastest animal movement ever recorded.

23
BILLION
TONNES

The mass of all of the microorganisms living under the surface of the Earth, as estimated by researchers at the University of Tennessee. That's several hundred times the mass of all humans on Earth.



AI RECREATES PAINTINGS USING 3D PRINTING

Call him Vincent van Bot: a team at MIT has created an artificial intelligence that can faithfully reproduce works of art. Dubbed RePaint, the system uses a combination of 3D printing and deep learning to authentically recreate complex paintings. It could be used to remake famous artworks for the home, or even to produce accurate copies to protect originals from suffering wear-and-tear when hung in museums.

"The value of fine art has rapidly increased in recent years, so there's an increased tendency for it to be locked up in warehouses away from the public eye," said RePaint mechanical engineer Mike Foshey. "We're building the technology to reverse this trend, and to create inexpensive and accurate reproductions that can be enjoyed by all."

The team used RePaint to reproduce a number of oil paintings created especially for the project by an artist. They developed a technique called 'color-contoning', which involves using a 3D printer to lay down translucent inks in thin layers, much like the wafers in a Kit-Kat. They combined this with an established technique called 'halftoning', where an image is created by lots of little ink dots, rather than continuous tones. This more fully captures the nuances of the colours in the original works.

At this time, the reproductions are only about the size of a business card, due to the time-costly nature of printing and the limited number of inks available to them. In the future, the team expects that more advanced, commercial 3D printers could help them to make larger paintings.

The texture of an artist's original work (bottom) can now be reproduced with AI-controlled 3D printing (top)

"OCD IS A DISORDER OF SPECIFIC BRAIN CIRCUITS"

What causes obsessive-compulsive disorder? Dr Luke Norman of the University of Michigan combined data from multiple studies to find the brain networks involved

What is obsessive-compulsive disorder (OCD)?

OCD has two primary symptoms. First are the obsessive thoughts, which often revolve around fears of harm occurring to the person with OCD or their loved ones. The second symptom is the compulsive behaviours, which are a way the person tries to regulate their anxiety. Compulsions can be linked with the obsessions – somebody who fears contracting a disease might keep washing their hands. But the compulsions can also be unrelated: the person with OCD might think an event is more likely to happen if they fail to perform an action a certain number of times, for instance. For diagnosis purposes, we typically say the illness should interfere for at least an hour a day and cause significant impairment.

Why study brain scans?

It's been hypothesised that brain networks involved in error processing and the ability to stop inappropriate behaviours – inhibitory control – are important in OCD. This is often measured in experimental tests like the stop signal task: participants are asked to press a button every time they see a picture on a screen, unless they hear a sound after the image is displayed. Previous

studies that used this type of task within a functional MRI scanner to look at abnormalities in brain activation have provided inconsistent findings, possibly due to small sample sizes. We collected data from 10 studies and put them together in a meta-analysis with a combined sample of 484 participants.

Which brain networks are involved?

OCD is a disorder of specific brain circuits. We think there are two main ones. First the 'orbito-striato-thalamic circuit', involved particularly in habits – it's physically enlarged in OCD and over-activated when patients are presented with pictures or videos related to their fears, so it works like an accelerator pedal on compulsive behaviours. The second is the 'cingulo-opercular network', which is involved in detecting when you need to engage greater self-control over your behaviour. In our meta-analysis, we found that patients showed increased activation in this brain network, but they performed more poorly during the inhibitory control task itself. The cingulo-opercular network is like a brake on ongoing behaviour: while patients with OCD show more activation in this brain network, it's not bringing



about the subsequent changes in behaviour that we would normally see in healthy people.

What have you found out about treatments for OCD?

Psychotherapy is very important for OCD, particularly cognitive behavioural therapy. This involves getting patients to gradually approach

the things they're afraid of and learn that bad things don't happen when they're exposed to OCD triggers. We're doing a big study on that now, looking at brain scans before and after treatment, to examine whether the two brain networks show more normal activation patterns as patients get better. Scientists have also been exploring repetitive transcranial magnetic stimulation to target the cingulo-opercular network. It does appear to have quite good efficacy for OCD.



DIGESTED READ

One circuit in OCD sufferers' brains is enlarged and works like an accelerator for compulsive behaviours. Another circuit, which detects when greater self control needs to be exercised, serves as a brake, but doesn't perform as well as the equivalent in healthy people. In essence, OCD sufferers know they need to slow down, but their brake pedal isn't working as well as it needs to.



ENDURANCE ATHLETES

If you want to live long and prosper you'd better get your trainers on. Researchers at Leipzig University have found that endurance exercise like running or cycling fends off the negative effects of ageing more better than working out with weights.

MARRIED COUPLES

A study of 87 older married couples carried out at the University of California has found that as couples aged, they showed more tenderness towards one another. The results challenge the idea that emotions flatten in old age.

GOOD MONTH

BAD MONTH

RESTAURANT DINERS

Those watching their waistlines in the New Year should probably steer clear of eating out. Researchers at the University of Liverpool have found that meals served in restaurants average 1,033 calories, that's almost twice the maximum of 600 per meal recommended by the BMJ.

UNTIDY WORKERS

It looks like it's time to tidy up that desk: a study at the University of Michigan has found that people with messy workspaces are judged to be more careless, cranky and less conscientious than their tidier colleagues.





HUMANS

CAVE PAINTINGS REVEAL ANCIENT EUROPEANS' KNOWLEDGE OF THE STARS

Ancient people across Europe might have known more about the stars than we give them credit for, according to a new analysis of cave art from the University of Edinburgh.

Some of the world's oldest cave paintings are now thought to depict not wild animals as was previously thought, but constellations in the night sky. This suggests that in these artworks, people were using the positions of constellations to represent dates, and mark events such as comets hitting Earth.

The researchers looked at Palaeolithic and Neolithic art featuring animal symbols at sites in Turkey, Spain, France and Germany. The examples of art they looked at varied in age by tens of thousands of years, but the system for representing dates with constellations appears to be constant throughout.

Some of the art in question dates back as far as 40,000 years ago, around the time Neanderthals became extinct.

Scientists work out the age of cave art by chemically dating the paint used. The team compared these dates to what the night sky would have looked like during known points in history, by using software to simulate the ancient sky.

The positions of the stars in the night sky changes slowly over thousands of years, as the Earth's rotational axis shifts. This new analysis shows that ancient people could define dates to within 250 years by using constellations as a reference.

"Early cave art shows that people had advanced knowledge of the night sky within the last ice age," said study leader Dr Martin Sweatman: "Intellectually, they were hardly any different from us today."

Cave art suggests that ancient people had a good grasp of the night sky, and drew images of animals to depict constellations

ZOOLOGY

SPIDER FOUND NURSING ITS OFFSPRING WITH MILK

The words 'spider' and 'milk' are not two that you'd generally expect to see in the same sentence. But that's exactly what researchers at the Chinese Academy of Sciences in Yunnan have found: a spider mother feeding her offspring with her own milk.

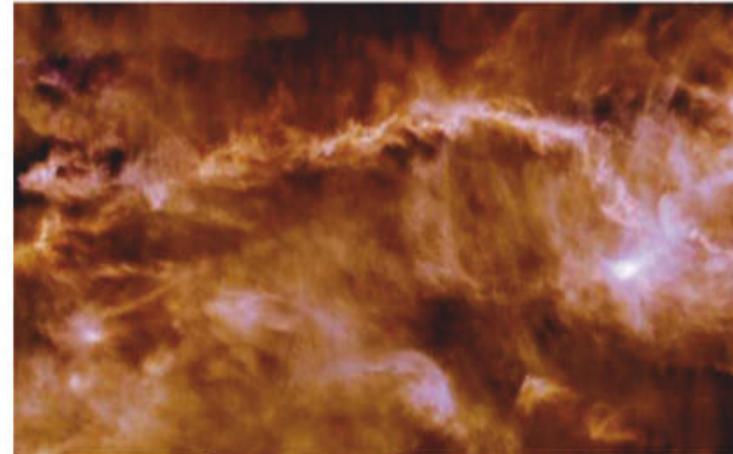
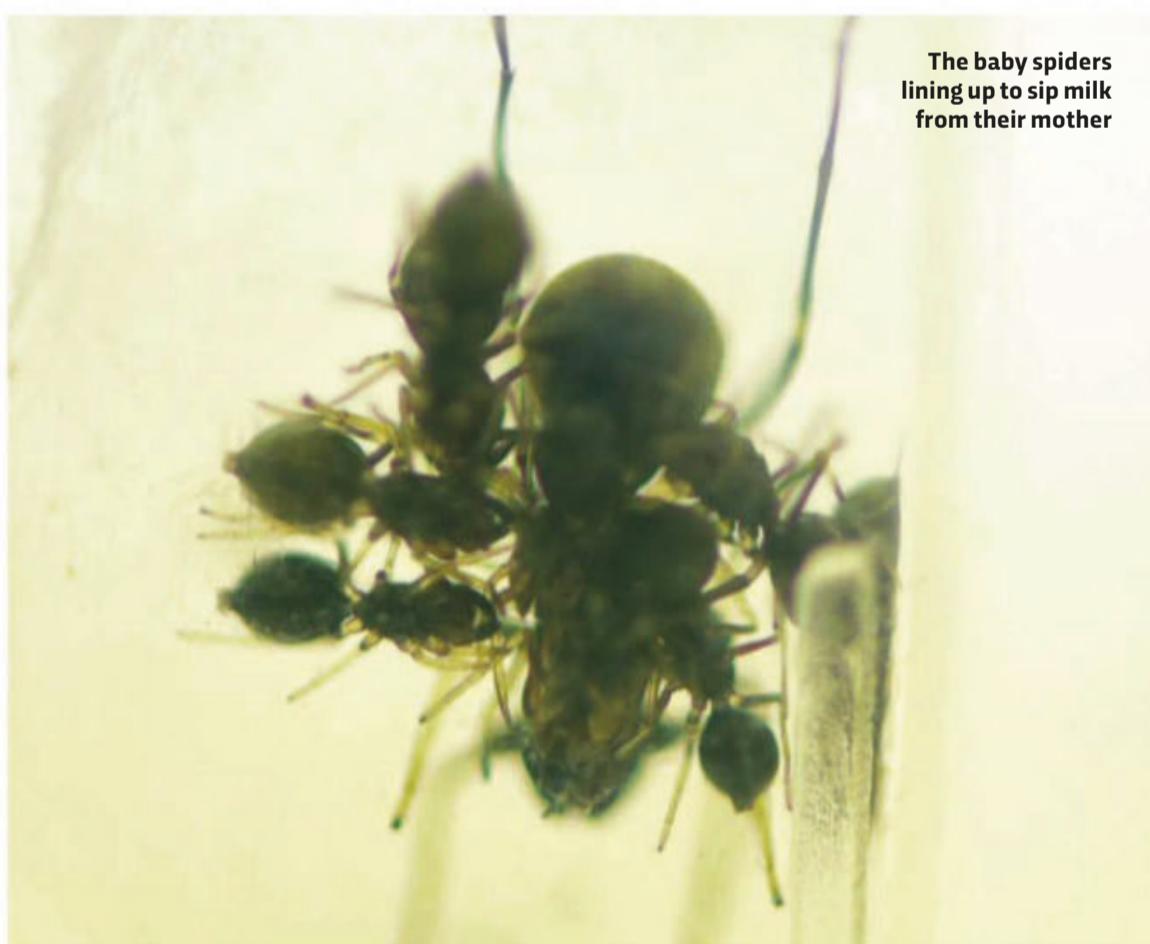
The behaviour was seen in a species of ant-mimicking jumping spider found in Taiwan called *Toxeus magnus*. The researchers first made the discovery after noticing a baby spider hanging onto its mother in the lab, in a way that reminded them of a baby mammal.

Mothers producing milk for babies is usually behaviour confined to mammals, but some bird species can produce something known as 'crop milk' and use it to feed their young. The intensive parental behaviour seen in these spiders, however, is rare.

Female spiders of the species lay up to 36 eggs at one time. The researchers noticed that when the baby spiders first hatched, they sipped 'milk' that their mother had deposited in droplets around their nest. But before long, they began lining up to drink the milk straight from their mother's egg-laying tract, and they kept on doing this until they were 40 days old, well after they were old enough to forage for food themselves.

To test what they were seeing, the researchers painted the mother spider to stop the milk reaching her offspring. After they did this, spiders that were younger than 20 days old all died. When the mother was removed from the nest, older spiders grew more slowly and were less likely to survive to adulthood, suggesting the milk was giving them a significant advantage.

The baby spiders lining up to sip milk from their mother



SPACE

CLUSTER OF 'SUPER-EARTHS' FOUND HIDING IN DUST

A stash of alien planets found hiding in a dusty region where stars form could help scientists trace our Solar System's history.

Astronomers peered through the dust that fills a star-forming region just 450 light-years from Earth in the constellation Taurus, using the Atacama Large Millimeter Array observatory in Chile. They looked at 32 stars surrounded by protoplanetary discs. These discs, made up of dust and debris, are typically flat and uniform, spreading out around their star like a pancake. But 12 of them in this survey have gaps that can only be fully explained by the presence of planets forming around the stars.

The new stars are too bright for us to see any of their planets directly, so the researchers did some calculations to work out how big these likely planets were. While two discs could be harbouring planets up to gas giant Jupiter's size, the rest are a maximum of 20 times the mass of Earth, making them either super-Earths or Neptune-like planets, depending on if they're rocky or made of gas.

Over 4.5 billion years ago our own Solar System was a swirling disc of dust around the Sun. Astronomers use observations of other solar systems to test their theories about what happened when our own star and its planets formed.

The finding also backs up astronomers' suspicions that super-Earths and Neptune-like planets are the most common outside of our Solar System. "This is fascinating because it is the first time that exoplanet statistics, which suggest that super-Earths and Neptunes are the most common type of planets, coincide with observations of protoplanetary discs," said Feng Long, paper author and PhD student at Peking University in Beijing, China.

PALAEONTOLOGY

SKELETON OF AUSTRALIA'S MARSUPIAL LION REBUILT

THEY DID WHAT?!



DOCTORS SWALLOWED LEGO... DELIBERATELY

What did they do?

A group of six paediatricians based in Australia and the UK swallowed the heads of LEGO figures. They then developed two metrics: the Stool Hardness and Transit, or SHAT score – a measure of stool consistency and time taken to pass the LEGO; and the Found and Retrieved Time, or FART, score – simply the number of days the LEGO took to come out the other end.

What did they find?

The LEGO passed through each of them without complication in an average of one to three days.

Why did they do that?

To reassure parents that small objects commonly ingested by young children can pass through their bodies without causing harm. "No parent should be expected to search through their child's faeces to prove object retrieval," they added.

The first-ever complete reconstruction of the skeleton of Australia's extinct marsupial lion reveals the animal to have been a fearsome ambush predator and an adept climber.

An analysis of several sets of remains of *Thylacoleo carnifex*, including one nearly complete fossil, carried out at Flinders University has allowed researchers to reconstruct the animal's entire skeleton for the first time.

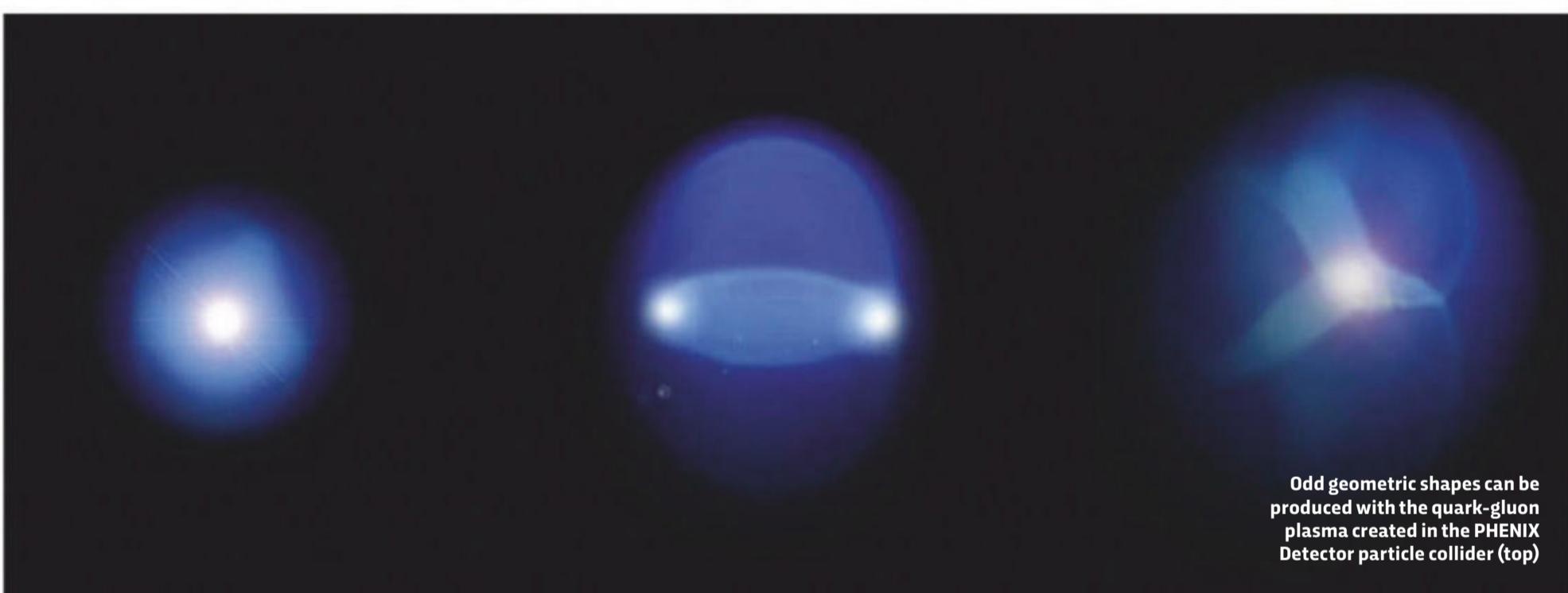
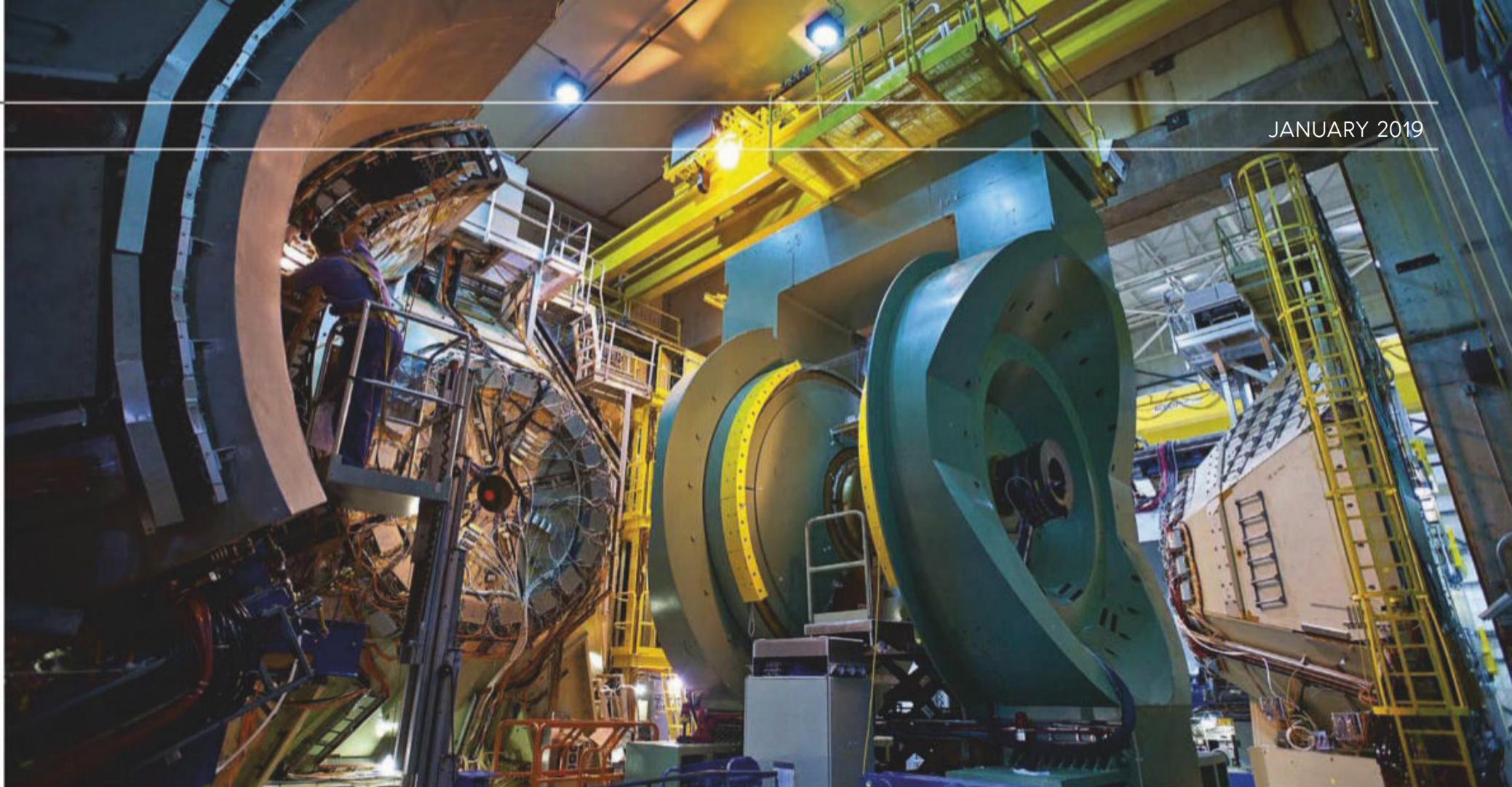
The extinct marsupial lion lived in Australia during the Pleistocene. It was first discovered in 1859 from skull and jaw fragments collected at Lake Colongulac, and was later sent to the British Museum in London. It has remained something of a mystery ever since.

The new fossils, discovered in Komatsu Cave in Naracoorte and Flight Star Cave in the Nullarbor Plain, include the first known remains of the tail and collarbone of *T. carnifex*. Analysis of the fossils shows it had a rigid lower back and powerful forelimbs anchored by strong collarbones, likely making it poorly suited for chasing prey, but well adapted for ambush hunting and scavenging. Its tail was likely stiff and heavily muscled, allowing it to perch on its hind limbs in a tripod position as it used its forelimbs for handling food or climbing. The anatomy of *T. carnifex* appears most similar to the Tasmanian devil, a modern-day carnivore that exhibits many of these inferred behaviours, researchers say.

Recently discovered remains of the extinct *Thylacoleo carnifex* have forced a rethink of the marsupial lion's biomechanics



GETTY, JAVIER ORJUELA KOOP ILLUSTRATION: DANIEL BRIGHT



Odd geometric shapes can be produced with the quark-gluon plasma created in the PHENIX Detector particle collider (top)

PHYSICS

SCIENTISTS CREATE STRANGE MATTER THAT ONCE FILLED UNIVERSE

Physicists at the University of Colorado have created tiny blobs of the bizarre liquid-like matter that filled the Universe milliseconds after the Big Bang.

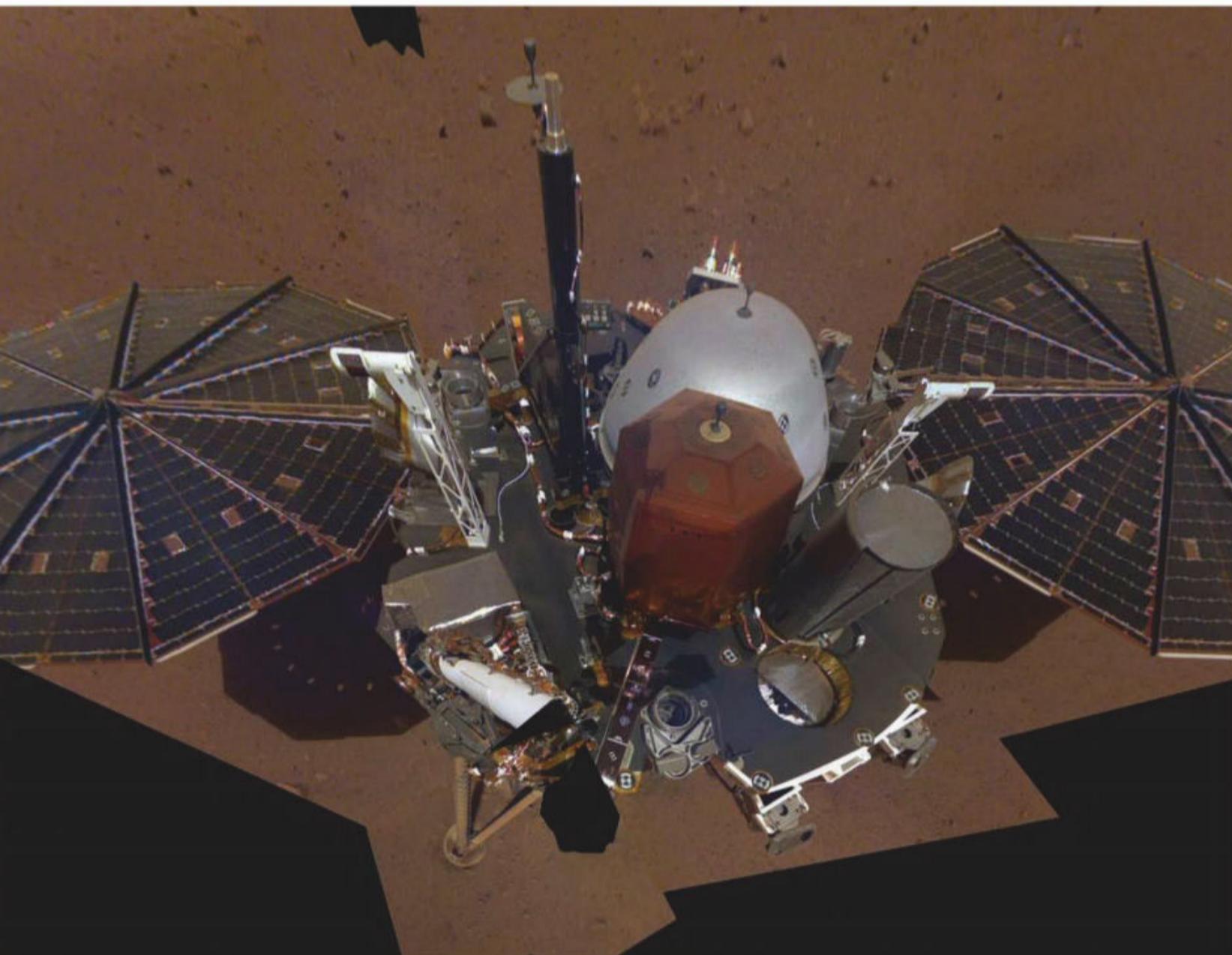
The team created the so-called quark-gluon plasma by smashing packets of protons and neutrons into a much heavier gold atom in the PHENIX Detector particle collider at Brookhaven National Laboratory in Upton, New York. It is theorised that this matter filled the entire Universe shortly after the Big Bang when it was still too hot for particles to come together to make atoms.

The physicists discovered that the droplets of quark-gluon plasma behave in a liquid-like manner expanding to form different geometric patterns – circles, ellipses and triangles – depending on the

type of particle used. Shooting the gold with a proton creates a circular pattern; shooting the gold with a deuteron, or proton-neutron pair, created an ellipse; while shooting the gold with a helium-3 atom, or two protons and a neutron, created a triangle.

“Imagine that you have two droplets that are expanding into a vacuum. If the two droplets are really close together, then as they’re expanding out, they run into each other and push against each other, and that’s what creates this pattern,” said Prof Jamie Nagle.

Further study of the process could help theorists better understand how the Universe’s original quark-gluon plasma cooled over time, giving birth to the first atoms in existence, they say.



SPACE

INSIGHT SENDS BACK FIRST SELFIE FROM MARS

This self-portrait was taken by NASA's InSight lander using a camera attached to its robotic arm. It's a composite image made up of 11 shots joined together to show the lander perched on the Elysium Planitia, a broad plain that straddles the Red Planet's equator where InSight has been positioned since successfully landing in late November.

In the coming months the InSight team will manoeuvre the lander's instruments – a seismometer and a heat probe – into position in the surrounding area in order to begin taking measurements.

"The near-absence of rocks, hills and holes means it'll be extremely safe for our instruments," said InSight's principal investigator Bruce Banerdt. "This might seem

like a pretty plain piece of ground if it weren't on Mars, but we're glad to see that."

InSight's mission is to give the interior of the planet the equivalent of a full-body health check. It will measure Mars's 'pulse' by monitoring the frequency and magnitude of the seismic activity (otherwise known as 'Marsquakes') and check its temperature by keeping tabs on the heat flow beneath the planet's surface.

It's hoped that the data collected will help the researchers to figure out how rocky planets, such as Earth and Mars, were formed. Here on Earth, most of the evidence has been erased thanks to the movements of tectonic plates over billions of years. Once operational, InSight will continue to collect data for 709 sols – Martian days – the equivalent to 728 Earth days.

THINGS WE LEARNT THIS MONTH

BLINKING HELPS US TO COMMUNICATE

Rapidly blinking to a conversation partner encourages them to talk more, while longer, slower blinks indicate that they should speak less, researchers at the Max Planck Institute in the Netherlands have found.

FOSSIL RECORDS FROM THE SO-CALLED 'HUMAN AGE' WILL BE DOMINATED BY CHICKENS

For future inhabitants of the Earth, the Anthropocene – the geological epoch defined by human influence – will be most evident thanks to chicken bones. According to researchers from Leicester University, evidence of human impact on the planet will be easiest to detect by looking at the bones of domesticated chickens. More than 23 billion of the birds are alive on the planet at any given time, they say.

THE UTERUS MAY PLAY A ROLE IN MEMORY

In addition to growing babies, the uterus may also play an unexpected role in memory. Rats that have had their uteri removed performed worse in maze-based memory tests, a study at the University of Arizona has found. The effect could be due to hormones released by ovaries affecting the brain, say the researchers.

TRENDING

Your guide to the hottest topics in the world right now

#GENDER INEQUALITY



SEXIST MEN UNDERESTIMATE THEIR POWER

Heterosexual men who hold sexist stereotypes may underestimate how much power they have in their romantic relationships, which could lead to increased aggression toward their female partners, researchers at the University of Auckland have found. Men with more hostile sexist views felt they had less power in their relationships, and were more aggressive toward their partners by being critical or unpleasant, the researchers said.

BIASED RECRUITERS

A study carried out at New York University has found there's a bias against women for jobs requiring intellectual ability. The researchers suggest that the odds of someone deeming a woman suitable rather than a man were 25.3 percent lower when the job description mentioned intellectual ability.

#DEPRESSION

REGULAR OUTINGS GUARD AGAINST DEPRESSION IN THE ELDERLY

Regular visits to the cinema, the theatre or museums could reduce the chances of becoming depressed in old age, a team at University College London has found. Those attending films, plays or exhibitions every few months had a 32 per cent lower risk of developing depression.

DEPRESSION COMMON AMONG LGBQ+ TEENAGERS

Young lesbian, gay, bisexual and non-gender-conforming teens are four times more likely to have felt depressed, harmed themselves or thought about suicide than cis/straight teens, a survey carried out by NHS digital has found. Almost 35 per cent of the 14 to 19 year olds interviewed who identified as LGBQ+ had a mental disorder, compared with 13 per cent of those who said they were heterosexual.



#CLIMATE CHANGE

SHORT WINTERS = MORE FOREST FIRES

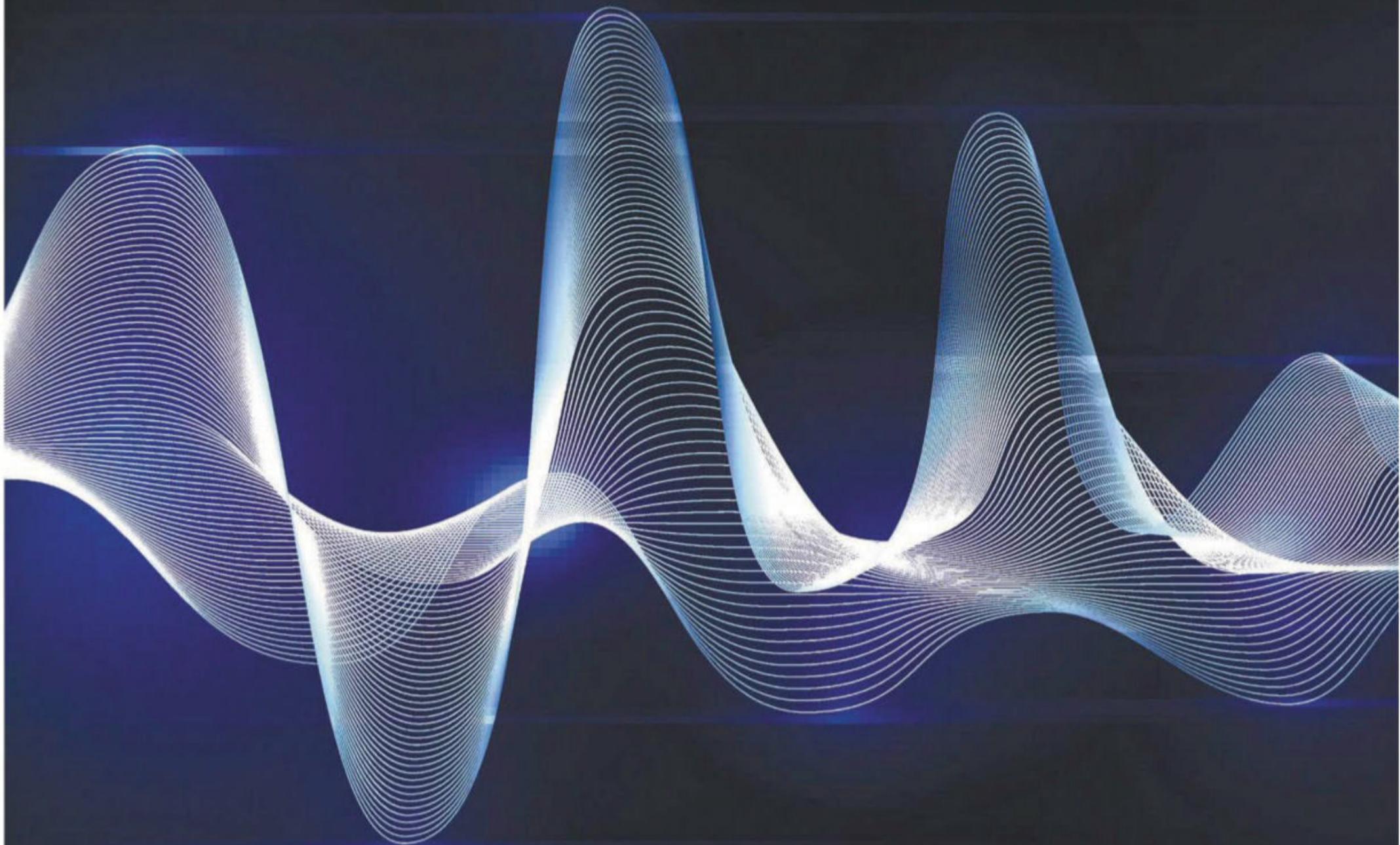
Californian winters are being squeezed into a shorter period leaving the state at risk of forest fire outbreaks for longer periods each year, scientists from the Scripps Research Institute have found.

HUMAN ACTIVITY IS REVERSING COOLING TRENDS

A study at the University of Wisconsin-Madison has found that human activity over the last 200 years is reversing a long-term cooling of global temperatures dating back at least 50 million years. If current emission trends continue, Earth's climate may resemble the mid-Pliocene epoch, which lasted from 3.3 million to 3 million years ago, by 2030. During this period average global temperatures were around 3°C higher than today, there was little ice in the northern hemisphere and sea levels were around 20 metres higher than at present.

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LET'S WIDEN OUR SOCIAL CIRCLES



Aleks Krotoski is a social psychologist, broadcaster and journalist. She presents BBC Radio 4's *Digital Human*.

There's something so refreshing about a new year. It's like going to an office stationery superstore: huge opportunities to restructure your life in a way that will make everything go smoothly and efficiently. And with coloured pencils!

This year, though, is going to be pretty complicated. You may have experienced a sneak preview at the Christmas dinner table of what's to come in our increasingly divisive political climate as we march towards the next phase in our country's history. Globally, things aren't any better; it seems that conflict is on everyone's dance card. So how to resolve the inevitable interpersonal fisticuffs, while still embracing a changing world? While there are countless arcane theories in psychology that try to unpick the core components that divide us – mostly prejudice and stereotyping – it really is all about a simple idea: the people who are in, and the people who are out.

Everywhere you look, people are trying to be with their own people while pushing the others away. It's in newspapers, on the telly, in fashion, in baseball caps with witty slogans, in stadiums, in pubs and in posh clubs. There's no nuance, no elegance. It's pretty vulgar, really. But it's how we have evolved as a social species. In-groups and out-groups were necessary as we emerged from the primordial ooze, when resources were scarce. And we think they're necessary now: economic disparity, mass migration, climate change – these things are pushing people together in a possibly uncomfortable way.

When it comes to higher order solutions, I'll leave the politics to the politicians and instead attempt to dispassionately hide behind my specialist subject, psychology. The way that people like me have historically sought to reduce the combustion of in-groups and out-groups is to force them to sit together in a room and have a chat. Pre-emptive restorative justice, one might say. *Minority Report*'s pre-cog programme for the rest

"GLOBALLY, IT SEEMS THAT CONFLICT IS ON EVERYONE'S DANCE CARD"

of us. The granddaddy of this approach is 'intergroup contact theory' from the late Gordon Allport. He argued that this breaks down stereotypes and prejudice, and reduces discrimination. The research that flowed from this all pointed to the same thing: mixing people up mostly makes them feel better about the other group. And moving forward, those positive memories mediate future interactions between the two groups.

And this has generally been the case. Having a cuppa with someone different from you, and not trying to convince them of your argument or superiority, means less prejudice and less stereotyping. Within the last year, there's evidence that the contact hypothesis does reduce out-group avoidance, even when those interactions are online. In the *Journal Of Sex Research*, Prof Fiona White and her colleagues paired heterosexual and homosexual people in a collaborative online project, and measured their attitudes towards the other before and after the experiment. The effects were striking, particularly for the male heterosexuals in the experimental group: they reported less anxiety and sexual prejudice when they were paired with a gay woman.

Yet often, the internet is a simulacrum of the crowded offline world, with everyone retreating to the corners where the people they think are like them hang out. Maybe a late addition to the New Year's resolution list should be to reach out to someone who's not part of your gang, and talk about the weather or something innocuous. **It might make 2019 the smoothest year yet.** F



THIS YEAR, I MIGHT GO VEGAN...



BBC
TWO

Michael Mosley is a science writer and broadcaster, who presents *Trust Me, I'm A Doctor* on BBC Two. His latest book is *The Clever Guts Diet* (£8.99, Short Books).

The New Year is a good time to make resolutions. Along with the obvious ones like drinking less alcohol, doing more exercise and learning a new language, this year I am contemplating giving veganism a go. At least temporarily. And perhaps just for a couple of weeks.

As anyone who has not been living in a cave, gnawing on dead animals, must be aware, veganism has become far more popular in recent years. Many people are going vegan for health reasons, others due to ethical concerns. But just how easy is it to go vegan and what are the potential pitfalls?

A few months ago, my friend and colleague, Dr Giles Yeo, decided to go vegan for a month as part of our BBC series *Trust Me, I'm A Doctor*.

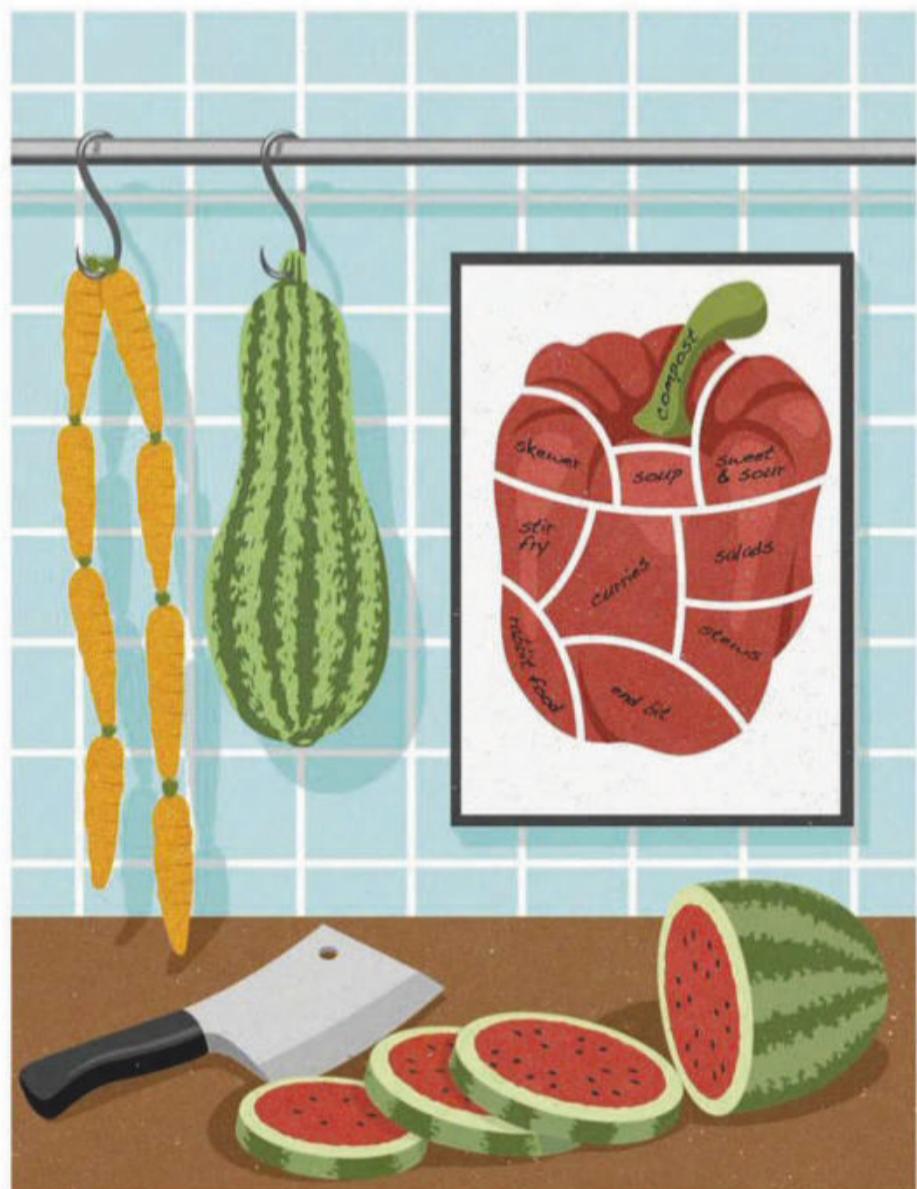
As Giles soon discovered, one of the tricky things about going vegan is that many products that don't sound as if they contain animal products actually do. You have to be super vigilant. Most commercial mayonnaises, for example, contain eggs, while wine often uses fish products as part of the production process.

You also have to be sure that you are consuming sufficient nutrients, such as vitamin D, calcium, iron, iodine (which in the UK is mainly found in cow's milk) and vitamin B12. You won't find much B12 in seeds, nuts or vegetables, so vegans and vegetarians need to keep their levels stocked up with fortified breakfast cereals or nutritional yeast.

But is going vegan a healthy way of living? Perhaps. A recent meta-analysis that lumped vegetarianism and veganism together concluded that giving up meat and meat products lowered the risk of developing heart disease and cancer but didn't have any measurable effect on 'all-cause mortality'. In other words, you might be healthier but you wouldn't necessarily live longer.

Giles did well on the vegan diet. After a month he had lost four kilograms and managed to shed a fair amount

"START WITH A DAY OR TWO OF BEING VEGAN PER WEEK"



of gut fat, enough to tighten his belt by a notch. His body fat went down by 2 per cent and his body mass index improved by 6 per cent. The other good thing was that his overall cholesterol levels fell by 12 per cent.

But the critical question is, will he keep it up? "I've been pleasantly surprised," he said. "Though I don't plan to go vegan entirely, from now on I'll try and do at least a few days every month. I have to admit I was apprehensive about going vegan for a month, but once I learned a few recipes I was fine and I actually ended up enjoying it. For me, the key was not to cook vegan versions of meals that I would normally eat with meat, but to opt for recipes that were designed to be vegan in the first place. What I missed most while on the diet was eggs – I actually expected to miss meat a lot more."

If you are not sure if you can handle going full-on vegan but still fancy giving it a go, then dietitian Dr Duane Mellor, who helped guide Giles through his vegan month, has this advice:

- Try replacing one product at a time, such as swapping cow's milk with a soy drink fortified with calcium.
- Try focusing on one meal at a time, such as lunches, before moving on to breakfasts and dinners.
- Start with a day or two of being vegan per week and work your way up to going plant-based full time.
- Practise cooking a few nutritionally balanced vegan meals that you enjoy. 

YOUR FREE PASSPORT FOR TIME TRAVEL

Genealogist Andrew Chapman sets you off on a unique journey thanks to your free subscription to **TheGenealogist** (worth £24.95)

With TheGenealogist, tracing your family history has never been easier. With this magazine, you have received an exclusive invitation to sign up for a free, three-month Gold subscription to The Genealogist. It has all the resources and tools you need to help you begin investigating your personal heritage.

STARTING YOUR VOYAGE

The golden rule of genealogy is to work backwards. Ideally you'll start with a date and a place for someone whose roots you'd like to explore. Family documents, such as letters, photographs, wills or newspaper cuttings, will also help. Remember: you will always need to corroborate what you find with actual records.

BIRTHS, MARRIAGES & DEATHS

Through birth, marriage and death indexes you can buy copies of original certificates from the General Register Office. The actual certificates open up more information: from dates of birth and names and addresses, to place of death, age and informant's details from deaths.

TEN-YEAR LEAPS

Census records available online span every ten years from 1841 to 1911. If you find your ancestor as a child, you'll then

have details of their parents and siblings. Their address is useful, too, as you may find your forebears stayed put from one decade to the next. TheGenealogist's Master Search feature allows you to search records by address as well as keywords, such as an occupation.

FINDING MORE DETAIL

Residential and trade directories dating back to the 1770s can tell you about the communities where your family lived. You'll find land ownership records from the 1870s, covering Britain and Ireland, plus extensive Rolls of Honour for WWI, army lists from the late 17th century up to 1940, and various navy lists from 1822 to 1944.

PUSHING BACK THROUGH TIME

The 500-year old parish record system gives you access to collections of baptism, marriage and burial records for more than 30 English counties and some parts of Wales, as well as a major collection of nonconformist registers covering Methodists, Baptists, Catholics, Quakers and other denominations. You will also have access to the vast collection of wills proved in the Prerogative Court of Canterbury (dated 1384-1858), plus wills from around 20 counties, dating from the 16th to 18th centuries.



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URGENT APPEAL: help Syrian refugee parents like Khitam to protect their children through the winter.



Khitam lives with her four young children, husband Abdelsalam, and his elderly parents in a single, damp room of a half-built apartment block near Tripoli, Lebanon.

There are holes in the walls and ceiling and they share a toilet with other refugee families crammed into the building. Khitam and Abdelsalam are mentally and physically exhausted after years of struggling to survive, unable to earn a living and fighting a daily, relentless battle to feed their children.

Right now, they are terrified by the prospect of another winter in their cold, uninsulated single room. Another winter where they will feel every blast of icy wind. Another winter where every time their children cough or sneeze they will fear they have contracted a lethal respiratory condition like pneumonia or tuberculosis.

UNHCR, the UN Refugee Agency, needs your



support to help parents protect their children this winter.

Please will you give £75 to provide a refugee family like Khitam's with a winter survival kit to protect against the freezing weather?

The kit contains essentials such as a heating stove, thermal blankets and a tarpaulin for insulation. It could mean survival for a family like Khitam's.

Last winter, as a result of their exposed and unsanitary living conditions, Khitam and all four of her children became ill. Baby Bilal had a high temperature and diarrhoea. Her sons Khaled (3, pictured) and Abdul Rahman (8) had chest infections and their sister Fatimah (4) contracted worms. Khitam



“Living here, in these conditions, I cannot keep my children healthy.”

© UNHCR/Hannah Maule-ffinch
© UNHCR/Andrew McConnell

herself developed painful growths on her throat and lost her voice. Without access to a free healthcare system like we have in the UK, Khitam became overwhelmed with worry about how to pay for the treatment and medicines her children needed.

“I felt helpless. My children were coughing and crying and there was nothing I could do.”

Khitam believes that

without assistance from UNHCR “my children would be dead”.

Across Lebanon and Jordan, six of the last seven winters have brought heavy snowfall and temperatures regularly drop below 0°C.

1.7 million Syrian refugees are living, like Khitam's family, in unfinished or derelict buildings, or in makeshift shelters, sometimes made of little more than wood and plastic sheeting.

This coming winter, when temperatures are likely to fall below zero, the lives of the most vulnerable: young children, pregnant women and the elderly, are at grave risk from hypothermia, frostbite and diseases like pneumonia.

With a gift of £75 you can provide a winter survival kit containing a stove, blankets, jerry can and a tarpaulin to help a family insulate and heat their home. Please give today – you could save the lives of children like Khitam's.

£75
could provide a Syrian refugee family with a winter survival kit

Give at unhcr.org/wintersupport
or call 020 3761 9525

With £75, you can give a winter survival kit containing:



STOVE
For heating and cooking. An absolute essential.



TARPAULIN
For insulation. Keeps the cold out and the warmth in.



BLANKET
Families left their homes with nothing. A simple blanket could save a life.



JERRY CAN
For storing fuel or water. Means people can avoid venturing out in the cold.

Yes, I will help Syrian refugee families survive the winter



Please accept my gift of: £75 £150 £225 My own choice of £

Please post urgently to: **Freepost UNHCR**. You do not need a stamp.

Please debit my: Visa MasterCard Maestro AMEX

Maestro only

Card no. - - - - -

Valid from - Expiry date - Issue no. - Maestro only

Signature Date / /

I enclose a cheque or postal order made payable to UNHCR

Please tell us if you are happy to hear more about UNHCR's work: By email By phone

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You can opt out of any communications at any time by emailing supportercare@unhcr.org or by calling 020 3761 9525

Title First name Last name

Address Postcode

Email Phone

BBFPRAW18

INNOVATIONS

PREPARE YOURSELF FOR TOMORROW

JANUARY 2019

EDITED BY HELEN GLENNY

FLEXIBLE FRIEND



Royole has brought the world's first foldable smartphone to market, speeding past tech giants in the flexible-screen innovation race. It's called the Royole FlexPai, and it's a 7.8-inch device that can be used flat as a tablet, or folded in half to roughly the dimensions of a normal smartphone.

One feature of flexible screens is that they're virtually unbreakable (the Royole FlexPai can withstand being folded and unfolded 200,000 times). When folded, users can answer calls and take photos from

both sides. It also has two cameras that can be bent to capture objects at unique angles. You can use the phone in single or split-screen mode, and even the 'spine' of the phone houses functions.

Samsung offered a sneak peek of their upcoming foldable phone at a developer conference in November last year, and it's rumoured that LG, Huawei and Motorola are working on their own versions. We're interested to see if they live up to the hype...

Royole FlexPai

From €1,338 (£1,210 approx), royole.com

1



2



3



4



5



6



WANTED

1 BULKY BRILLIANCE

This new VR headset is bulky and expensive, but it sports a 170° field of view and high-density OLED displays with 5K resolution. It detects your eyes and automatically adjusts its lenses so you can switch between users quickly.

VRgineers XTAL Smart VR Headset
\$5,800 (£4,580 approx), vrgineers.com

2 GROW SMARTER

The Akarina 01 smart garden comes with efficient LED lights, so you can cultivate herbs and vegetables year-round. It has a super-clean design and uses only liquid fertiliser, so it won't muddy up your kitchen units.

Akarina 01
£169.99, akarina.uk

3 ON THE WATCH

This minimalist Swiss-movement analogue watch tracks heart rate, sleep, steps and other fitness metrics. Its low-energy design means that it'll last 30 days on a single charge, even while receiving call and message notifications.

Oaxis Timepiece
\$179 (£142 approx), oaxis.com

4 SWEET DREAMS

For those who love sleep metrics but hate wearing watches to bed, there's now a sensor strip you can place under your sheets. Beddit sleep tracker will measure how well you're sleeping and monitor your breathing and snoring. Zzz.

Beddit Sleep Tracker
£149, beddit.com

5 WAKEY, WAKEY

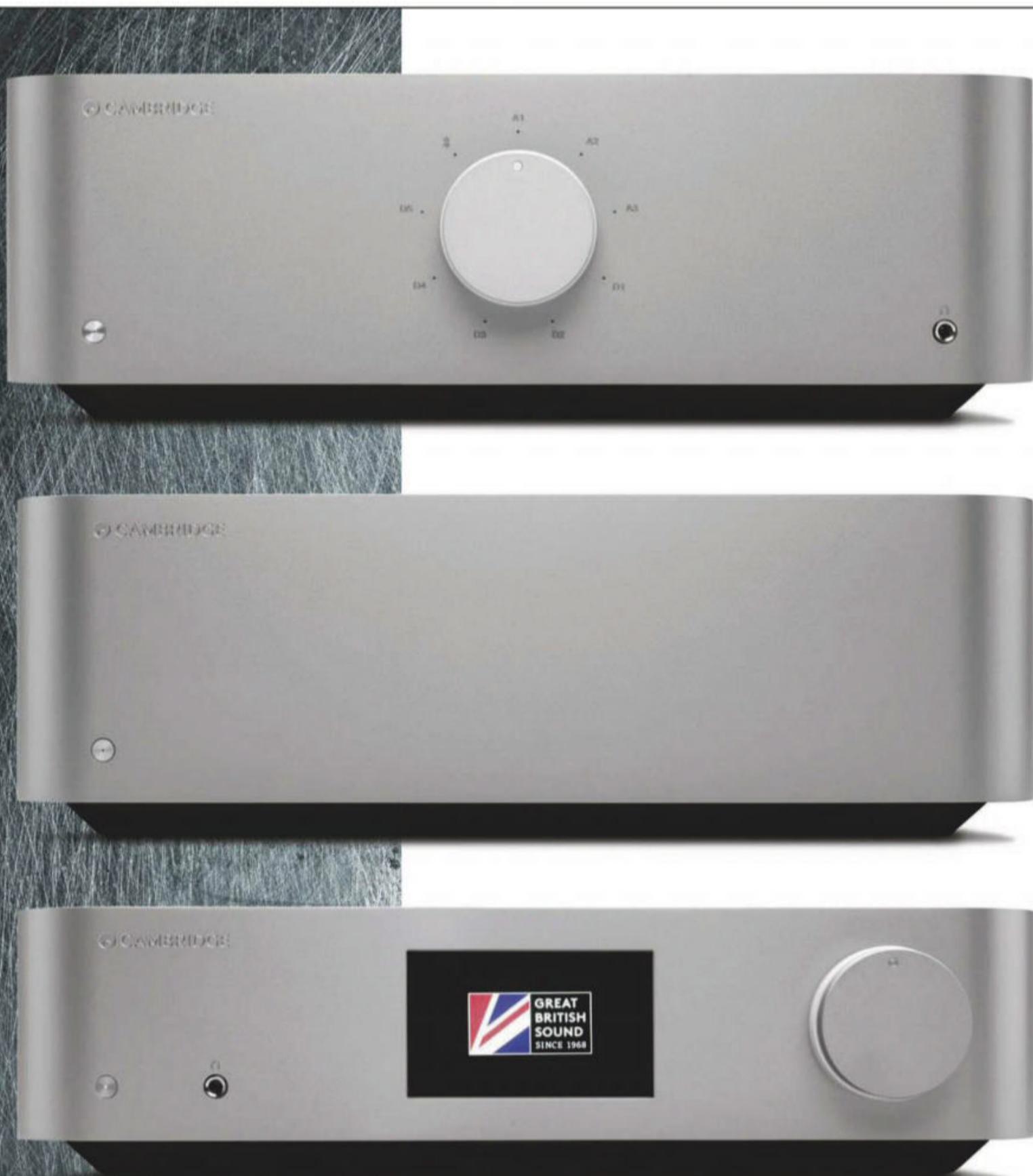
This alarm clock mimics sunrise, waking you gradually, which boosts mood and energy levels for the day ahead. It can accompany the sunrise with birdsong, crashing waves, or, if you fancy it, the aggressive bleats of a herd of goats.

Lumie BodyClock Shine 300
£125, lumie.com

6 RETRO TRACKER

Puma dabbled in high-tech exercise tracking in 1986, but the chunky-computer-in-the-heel look didn't catch on. The new edition replicates that look, but the data it collects can now be transferred via Bluetooth, rather than a 16-pin cord.

RS-Computer Shoe
€630 (£588), puma.com



A BIRTHDAY TREAT

British hi-fi company Cambridge Audio is celebrating its 50th birthday with an anything goes, no-holds-barred attempt to produce the best audio system it's ever made. The result is The Edge, a £10,500 hi-fi system that looks slick and sounds flawless. It consists of three units: Edge A, an integrated amplifier; Edge NQ, a preamplifier and network player; and Edge W, the power amplifier.

The focus of this three-year engineering project was sound first, everything else second. Cambridge Audio says that every component was selected

through blind auditions, with no consideration for price, specification or measurement. One important feature is the short signal path, which reduces the chance of colour or distortion interfering with the sound. In the Edge W power amp, there are just 14 components (typically, there'd be 30 or 40). The casing is clean, with volume and input controls on a single knob. While it's a step away from the company's usual affordable product lines, it's a fitting celebration of a successful half-century.

The Edge
£10,500, cambridgeaudio.com



HEALTH

WORLD'S SMALLEST WEARABLE GUARDS AGAINST SKIN CANCER

This solar-powered, virtually indestructible wearable measures UVB and UVA light to help users avoid the damaging effects of the sunshine. It was developed by researchers at Northwestern Medicine and Northwestern Engineering, and can even record light exposure in the water – perfect for long days playing at the beach.

Sunlight passes through a window in the wearable, then strikes a tiny photodetector. This produces a minute electric current that's proportional to the intensity of the light. The associated charge is stored, and that data is passed wirelessly to the user's phone. The device communicates with the user's phone to access weather and UV index information, and alerts them if they've been in the sun for too long.

“UV light is ubiquitous and carcinogenic. Skin cancer is the most common type of cancer

worldwide. Right now, people don't know how much UV light they are actually getting,” said dermatologist Dr Steve Xu, who co-authored the research.

The wearable can measure three wavelengths of light simultaneously. “Being able to split out and separately measure exposure to different wavelengths of light is really important,” said Prof John Rogers, who leads the research group. “UVB is the shortest wavelength and the most dangerous in terms of developing cancer. A single photon of UVB light is 1,000 times more erythrogenic, or redness-inducing, compared to a single photon of UVA.”

Designed for more than just tracking sun exposure, the device can also be used to measure white light for seasonal affective disorder (SAD), or in hospitals to monitor blue light phototherapy for newborns with jaundice.

The tiny wearable is about the size of a Smartie and can be worn on the fingernail, or even on a hat or sunglasses

ENGINEERING

RESEARCHERS ARE MAKING BACKPACKS FOR BUMBLEBEES

Drones are already being used for smart farming, to monitor crops and sense changes in the environment, but most can only fly for 20 minutes before their batteries run out. Bumblebees, on the other hand, fly for hours and are capable of carrying loads equal to their bodyweight. Researchers at the University of Washington have developed backpacks for bumblebees that allow them to carry sensors while they go about their day's foraging. The backpack weighs 102 milligrams and consists of a tiny chip loaded with a small, rechargeable battery that has enough juice for seven hours of use. The backpack has built-in sensors for monitoring temperature, humidity and light intensity. Because GPS is too power-intensive for the small battery, the backpacks are kitted out with receivers that communicate with antennas in the environment to triangulate the bees' positions.

While the backpacks will be a noticeable weight for the bumblebees, they're lighter than the weight of the pollen and nectar that bees often carry back to their hives. The researchers were also careful when handling the bees.

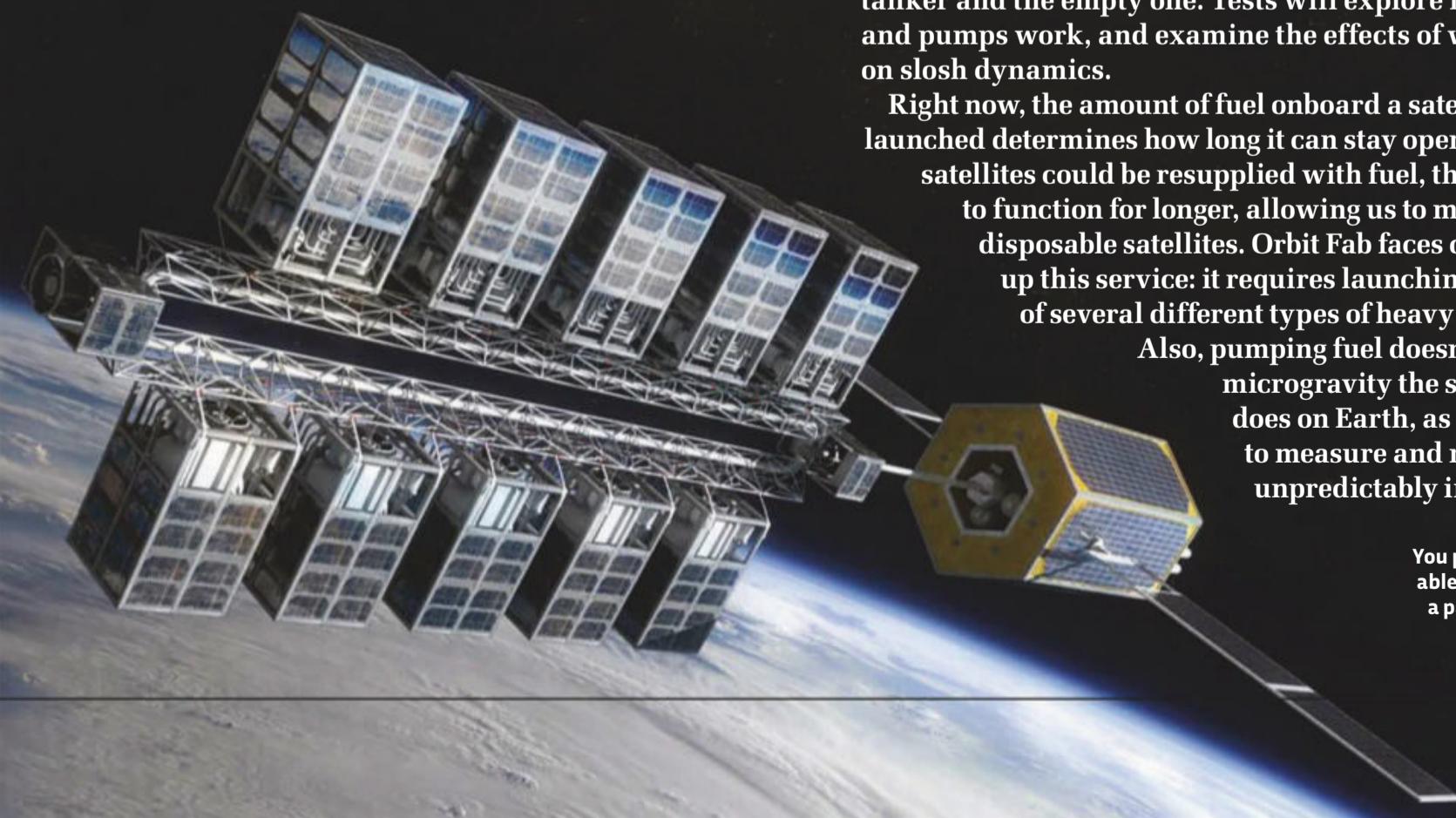


When the bees come back to their nest at the end of the day, the researchers can upload the data they've collected and wirelessly charge the backpacks, ready for another day of nectar- and information-gathering.

The information gathered by the bees could provide new ways to monitor agriculture and the environment, and also offer fresh insight into the lives of the insects

SPACE

PETROL STATIONS IN SPACE?



San Francisco-based start-up Orbit Fab has taken a step towards building the first fuelling stations in space. The company recently sent an experiment to the ISS, to test a method of fluid transfer that could soon be used to refuel satellites in orbit. The experiment involves two 'tankers', one of which was launched filled with water. Onboard the ISS, the water will be transferred back and forth between the full tanker and the empty one. Tests will explore how the valves and pumps work, and examine the effects of weightlessness on slosh dynamics.

Right now, the amount of fuel onboard a satellite when it's launched determines how long it can stay operational. If satellites could be resupplied with fuel, they would be able to function for longer, allowing us to move away from disposable satellites. Orbit Fab faces challenges setting up this service: it requires launching large quantities of several different types of heavy fuel into orbit.

Also, pumping fuel doesn't work in microgravity the same way as it does on Earth, as the fuel is harder to measure and moves around unpredictably in its tank.

You probably won't be able to buy coffee and a pastry at Orbit Fab's service station

HEATING UP

The cold weather's hitting its peak. Here's what the tech world can offer us in the fight against the winter chills...



HEAT SEEKER

This attachment turns your smartphone into a high-quality thermal imaging camera, allowing you to easily check where you might be losing heat from your house. With it, you can find out whether chunks of insulation need to be replaced, or if your home has water damage.

And once you've made sure your home is thermally efficient, you can use the device to cheat in a game of hide-and-seek. Don't worry, we won't tell.

Flir One Pro
From £370, flir.co.uk



BE SMUG IN THE SNOW

Blazewear's thick insulation keeps you toasty on cold winter days. But when it's seriously chilly, switch on the battery-powered heat pads located in the back and chest, and it'll feel like you've stuffed your jacket with hot water bottles. Plus, you can charge your phone off the battery pack. Instagram snow pics, here we come!

Blazewear Explorer Heated Jacket
From £199.99, blazewear.com



FEELING HOT (OR COLD)

This smart bracelet was designed by MIT graduates to stimulate your thermoreceptors. It delivers waves of heat or cold to the high-density nerves in your wrist, making you feel warmer or cooler without changing your core body temperature. It claims to be able to change your perceived temperature by 5°C in either direction.

Embr Wave
\$299 (£240 approx), embrlabs.com



GOODBYE, COLD TEA

Fill this travel mug with your tea or coffee, let it know your ideal temperature via the app, and it will notify you when your cuppa's perfect for drinking. You can also set the temperature by rotating a dial on the mug, so you don't need to use your phone when your hands are gloved up. Best of all, it keeps it at your required temperature for two hours, so you can enjoy every last drop.

Ember Travel Mug
£159.95, ember.com



SLEEP TIGHT

This dual-zone climate-controlled 'smart layer' slips inside your duvet cover, and lets you and your partner set your preferred temperatures. So if you're feeling chilly, warm air will be blown gently throughout your side of the bed. The smart layer also contains openings to allow any humidity to escape. If that wasn't clever enough, once you've installed it, your bed will inflate to make itself every morning.

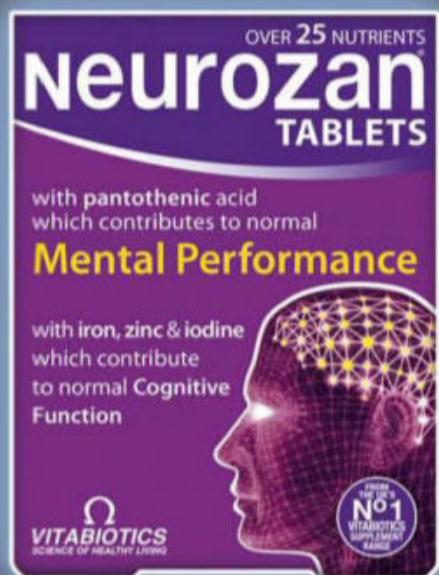
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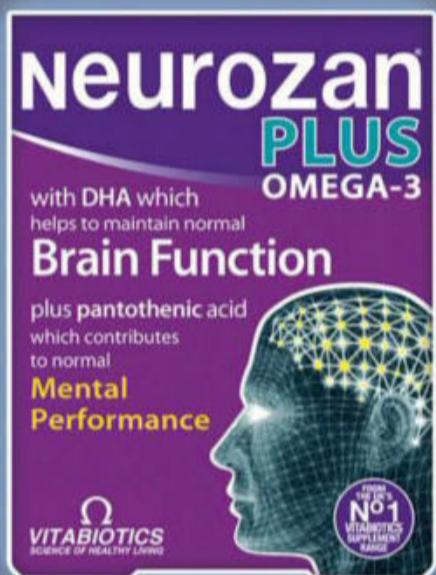
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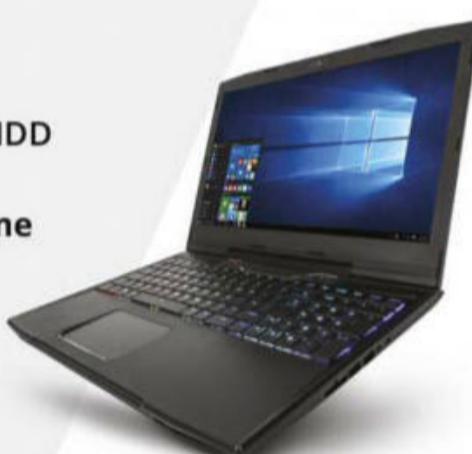
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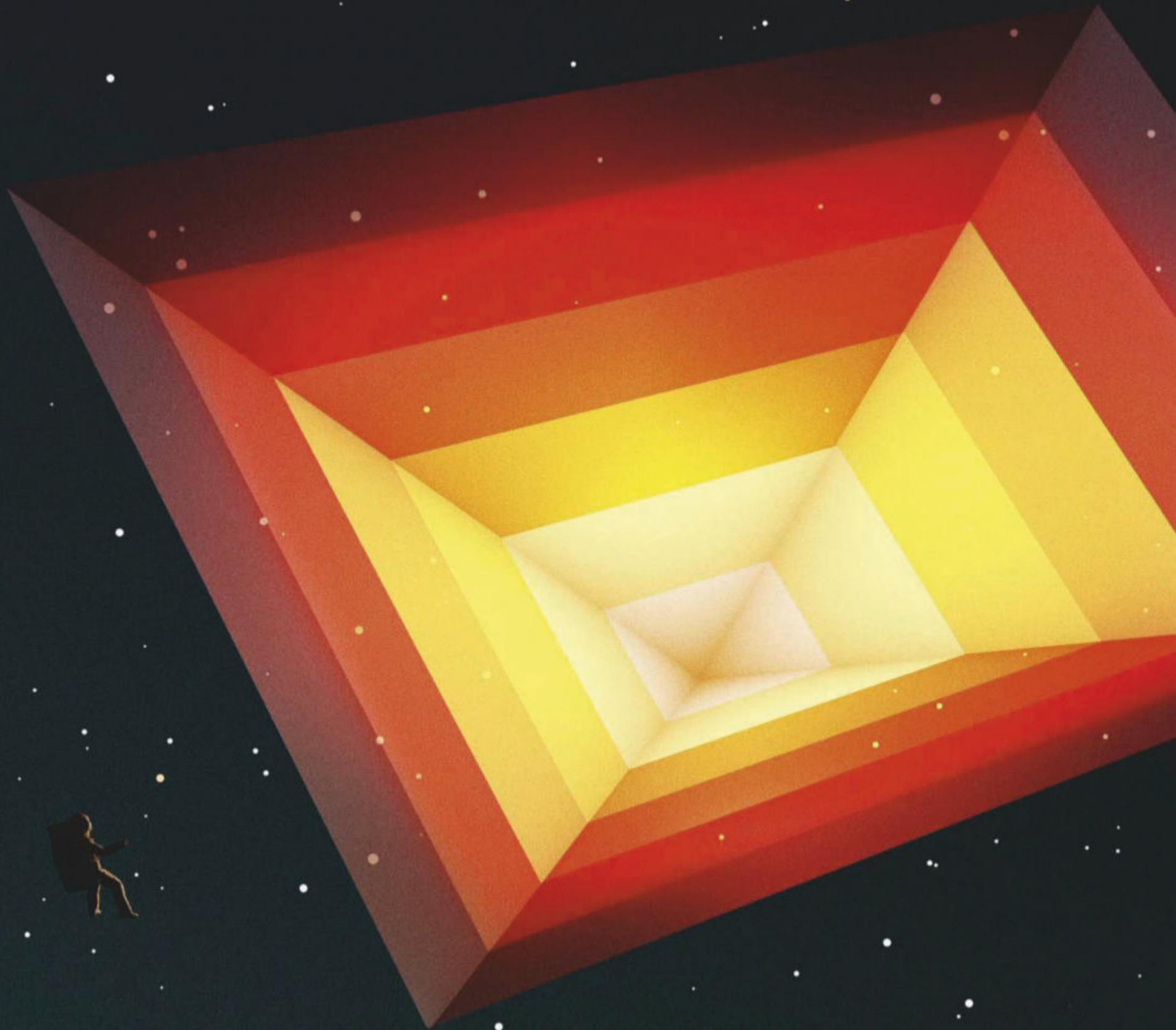
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The discovery in October 2017 of a bizarre, cigar-shaped object hurtling through our Solar System set imaginations racing. Was it an asteroid? A comet? Or an alien spaceship, sent here on a reconnaissance mission?

Named 'Oumuamua, it joined a select group of cosmic enigmas and celestial oddities that have astronomers scratching their heads...

WORDS: COLIN STUART

THE MOST
MYSTERIOUS OBJECTS
IN THE UNIVERSE

ILLUSTRATION: MAGIC TORCH

'OUMUAMUA

Could this cucumber-shaped object be an alien spacecraft from another galaxy?

The pages of sci-fi books are full of alien interlopers secretly entering the Solar System to snoop on humanity as we emerge as a technologically capable race. So it's no surprise that excitement started to build when, on 19 October 2017, the astronomer Dr Robert Weryk spotted an object whizzing through the Solar System while using the Pan-STARRS telescope at Haleakalā Observatory, Hawaii.

Dubbed 'Oumuamua (after the Hawaiian for 'scout'), this object is extremely elongated, possibly up to a kilometre long but not more than 167 metres wide, making it look like a space cucumber. It's travelling so fast that there's no way it can be gravitationally bound by the Sun. The only conclusion is it's an interloper that formed outside our Solar System and subsequently trekked all the way here. Estimates suggest it entered the Solar System in the Victorian era, but astronomers don't know exactly how long it wandered space alone before it got here. In August 2018, a study using data from the European Space Agency's Gaia telescope identified four stars that it would have passed close to in the last one to seven million years. Perhaps one of these was its home star.

So what is 'Oumuamua? At first, astronomers reckoned it was an asteroid, but a closer look at its motion threw up something strange: the Sun's gravity was not the only thing affecting its trajectory through space. This prompted some researchers, including Prof Avi Loeb at Harvard University, to suggest it could be an alien space

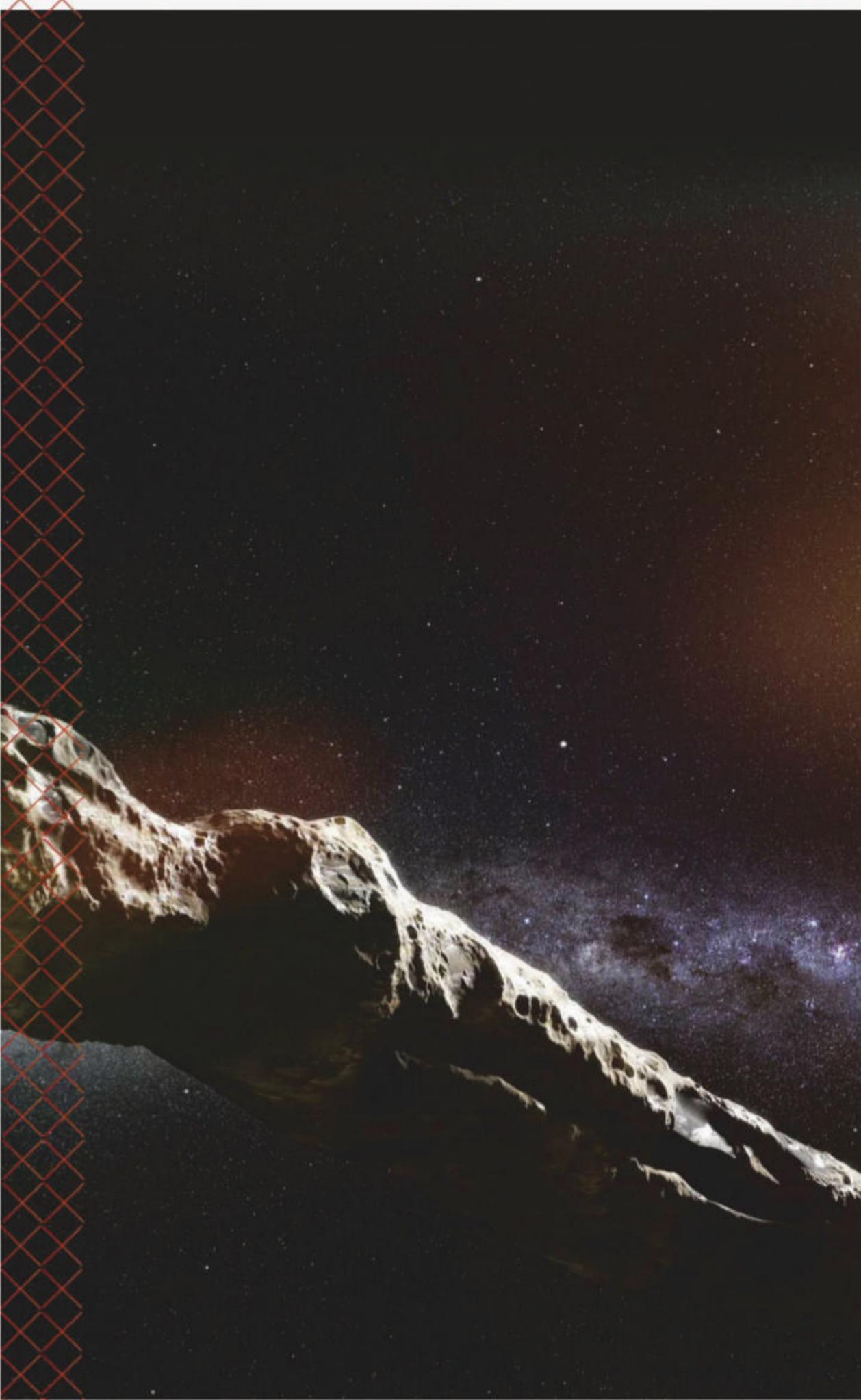
probe. If it had a solar sail attached, pressure from the solar wind could be helping to blow it off-course. But this idea has received a backlash from most quarters, and the object is more likely to be something entirely natural. "Most of the evidence points towards a comet," says Dr Colin Snodgrass, an astronomer at the Open University. Little jets of gas, caused when the comet's ice is warmed by the Sun, could be nudging it off its natural gravitational course.

"It has some unusual properties compared with comets from our Solar System, though," adds Snodgrass. "We are still trying to figure out what causes these." Typically, comets reflect about 4 per cent of the light that falls on them. 'Oumuamua is more than twice as reflective. Unfortunately, our chance for more observations is now over. 'Oumuamua has fled into the outer Solar System, journeying past Jupiter on a trajectory that will eventually see it leave our neighbourhood altogether. It's already too faint to see. Yet the controversy and ideas around this mysterious object continue to confound astronomers.

ABOVE: Artist's impression of 'Oumuamua

RIGHT: The harsh edges of the Red Rectangle Nebula are at odds with the swirling, curvy shapes that are usually seen in space





“ASTRONOMERS RECKONED IT WAS AN ASTEROID, BUT A CLOSER LOOK AT ITS MOTION THREW UP SOMETHING STRANGE”

GETTY, NASA/HUBBLE SPACE TELESCOPE

THE RED RECTANGLE NEBULA

The geometric shape of this gas cloud makes it a space oddity

Throughout the Galaxy, gas clouds take on weird and wonderful forms, but one nebula in particular is baffling astronomers with its oddly geometric shape. Located in the constellation of Monoceros (The Unicorn), the Red Rectangle Nebula sits 2,300 light-years away. Its distinctive shape could be due to the fact that two stars sit at its heart. If shock waves from both stars hit a dusty ring surrounding the pair, they could create two cones of bright dust. Seen together, these two cones look like a square. To add to the mystery, the nebula also exhibits a rare phenomenon called ‘extended red emission’, where its dust glows eerily red. It isn’t known exactly what causes this, but some researchers argue that it’s due to intense ultraviolet light from the stars interacting with carbon-rich molecules in the dust.



PLANET NINE

Could our Solar System be hiding a enormous ninth planet, out beyond the orbit of Neptune?

Could an enormous world be lurking in our midst? Astronomers are increasingly certain that there is a ninth planet orbiting the Sun, far out beyond Neptune – a so-called ‘Planet Nine’. It wouldn’t be the first time the roll call of the Sun’s orbiting worlds has been tweaked. When Ceres, the largest asteroid in the Solar System, was discovered in 1801, it was initially classified as a planet, but later downgraded. Pluto, too, was admitted to the planet club upon its discovery in 1930, only to be asked to leave in 2006 and relegated to dwarf planet status.

The first clues that there is yet another member of the Sun’s planetary fraternity came in 2014 when American astronomer Dr Scott Sheppard found a small dwarf planet candidate called 2012 VP113, orbiting an average of 250 times further from the Sun than the Earth. Its elongated orbit, which is significantly tilted relative to that of the planets, immediately stood out. “Nothing is currently known in the Solar System that could create 2012 VP113’s orbit,” says Sheppard.

While a few unusually aligned objects could be dismissed as an unlikely coincidence, now a total of 10 have been discovered, largely thanks to work by astronomers Dr Mike Brown and Dr Konstantin Batygin at the California Institute of Technology. With all of these objects sharing similar orbital properties, the chances of their alignment being a fluke drops to just 0.0001 per cent. The leading explanation is that there is an otherwise unseen planet herding these objects with its gravity.

Sheppard was 60 per cent sure a ninth planet existed back when he found 2012 VP113. Now he says he’s 85 per cent certain. Yet for the planet to be acting in this way, it would have to be 10 times more massive than the Earth, take at least

ABOVE: Artist’s impression of Planet Nine, which could be shaping the orbits of objects beyond Neptune

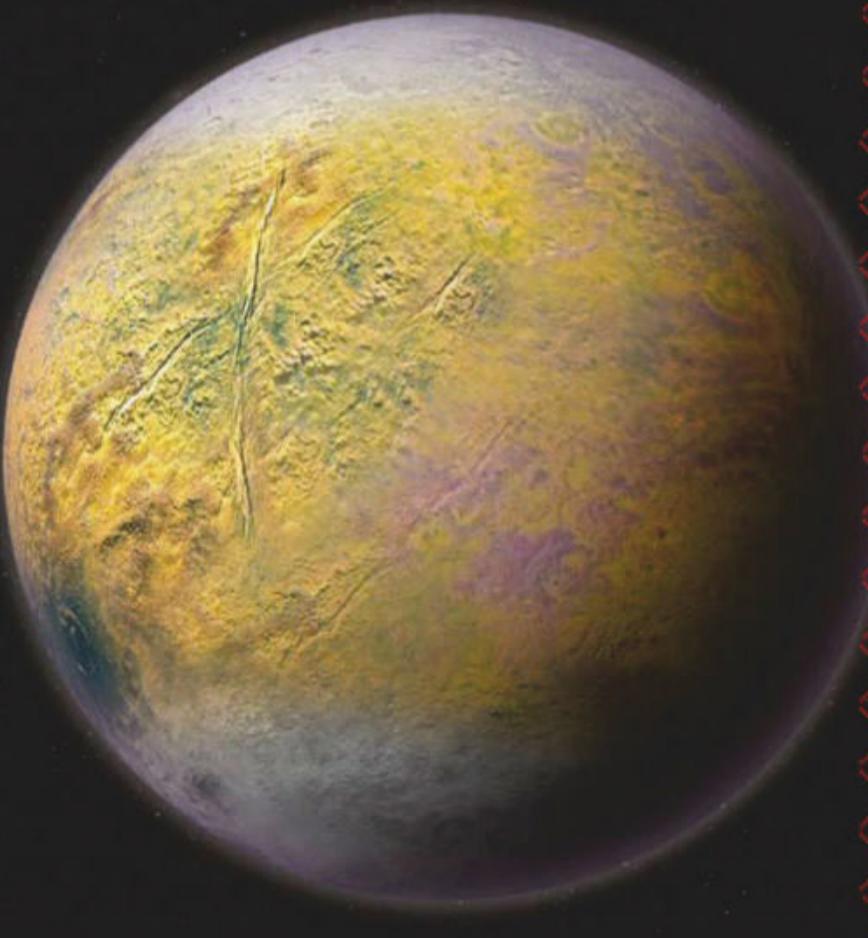
RIGHT: The galaxy Dragonfly 44 seems to be made of 99.9 per cent dark matter

FAR RIGHT: Elst-Pizarro can be seen zooming across the middle of this image, taken by the Schmidt telescope at La Silla Observatory

“IT WOULD HAVE TO BE 10 TIMES MORE MASSIVE THAN THE EARTH”

10,000 years to orbit the Sun, and sit over 200 times further out than our planet.

This enormous distance makes hunting it down and photographing it tricky. For us to see Planet Nine, light has to trek all the way out there from the Sun and almost all the way back again, fading all the while. But astronomers have been able to narrow the search using several clever shortcuts. For example, data from the Cassini mission to Saturn was used to rule out parts of the outer Solar System. If Planet Nine was in those areas, then the probe would have picked up small gravitational discrepancies. There was a small setback in September 2018 when new research showed that another technique for ruling out parts of the sky wasn’t feasible. But the hunt goes on. “So far we have covered about 30 per cent of the prime area the planet could be in,” says Sheppard. It’ll take about another four years to cover the rest.

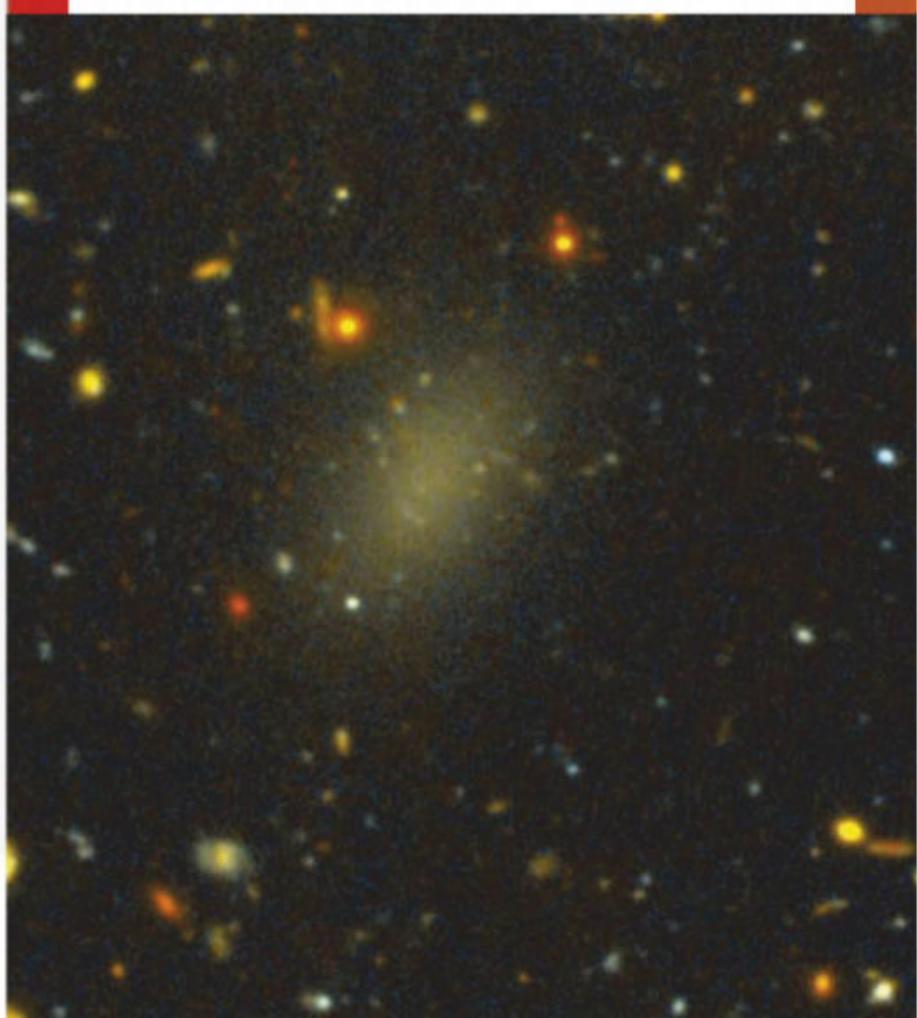


GALAXY X

A galaxy comprised of dark matter may orbit the Milky Way

Astronomers are good at finding new objects by spotting their effects on their more conspicuous neighbours. Neptune was discovered thanks to its influence on Uranus; black holes show themselves by the stars they bind into orbits around them. So when astronomers saw odd ripples in the disc of the Milky Way in 2009, thoughts naturally turned to some unseen disrupter. In 2015 they found the culprit: a dark, dwarf galaxy orbiting the Milky Way, subtly altering the motion of our Galaxy with its gravitational pull. We can only see this galaxy thanks to four bright stars that shine out of the gloom. Otherwise, the galaxy lurks in the shadows. To be this hard-to-see, 'Galaxy X' must be largely made of dark matter – the invisible glue that binds galaxies together. In normal galaxies, this dark matter is peppered with visible stars and hot gas strung out like Christmas lights. In Galaxy X, it's as if all the lights have gone out.

In 2016, a Milky Way-sized galaxy known as Dragonfly 44 was found to be made of 99.99 per cent dark matter. It joined Segue 1, a dwarf galaxy discovered in 2006 that subsequent observations showed contains 1,000 times more dark matter than ordinary matter. That compares to a ratio of around 20 to 1 in our own Milky Way. Little is known of the origins of these ghostly galaxies, but studying them may help us to understand what dark matter itself is made of.



CARNEGIE INSTITUTE FOR SCIENCE, PIETER VAN DOKKUM/ROBERTO ABRAHAM/GEMINI OBSERVATORY/SDSS/AURA, ESO

ELST-PIZARRO

Is it an asteroid? Is it a comet? This object seems to have properties of both

Normally it's easy to tell asteroids and comets apart. Asteroids are solid lumps of rock and metal, capable of careering into planets and killing dinosaurs. You typically find them in the inner Solar System, particularly in the asteroid belt between Mars and Jupiter. Comets, on the other hand, are icy bodies that form on the outskirts of the Solar System. On their rare forays towards the Sun, their frozen bodies react with solar radiation to create spectacular tails.

An object known as Elst-Pizarro, however, refuses to be so neatly pigeon-holed. When it was first discovered in 1979, its orbit in the asteroid belt led to it being classified as an asteroid. Yet when it was examined more closely in 1996, it showed itself to have a tail – like a comet.

Astronomers first thought that the tail was debris from a collision, rather than something bestowed by the Sun's heat. But the tail's brightness and structure changed over time – pointing to an ongoing process, rather than a one-off event. The object's rapid rotation – completing a full spin in just 3.5 hours – also said comet. One possibility, however, is that a collision has exposed some subsurface ice on the body which is slowly being lost to space. In this case, Elst-Pizarro would be an asteroid masquerading as a comet – until it has shed all of its exposed ice and gone back to being a standard asteroid again. Arguments still rage between astronomers. To settle them once and for all, space scientists had hoped to launch the Castalia spacecraft for a closer look in 2028. However, the mission failed to get the green light in the European Space Agency's 2016 round of funding. So the disagreements continue, for now at least.

TABBY'S STAR

The constellation of Cygnus has an unusual star, with a fluctuating brightness that has left scientists scratching their heads

'Oumuamua isn't the only object that has got people talking about alien technology. Extraterrestrials have also been implicated in the mysterious dimming of Tabby's Star. Located nearly 1,500 light-years from Earth in the constellation Cygnus, it is named after the astronomer Tabetha Boyajian. She was the lead author of a 2015 study which showed that the star occasionally rapidly drops in brightness by a whopping 22 per cent. The star's overall brightness has also been seen to fade more slowly over several decades. The short-term variation was picked up by the Kepler space telescope, whose job it was to find alien planets by analysing the light of distant stars, looking for dips in their starlight as a planet passed in front of them. However, unlike the dimming of Tabby's Star, the dimming caused by planets is evenly spaced, as it happens

each time the alien world completes an orbit, and is also relatively small – normally under 1 per cent. "Tabby's Star just keeps getting weirder and

weirder," says astrophysicist Dr Eva Bodman at Arizona State University.

So what else could be dimming the star? One idea is that a swarm of comets is plunging into the inner regions of the star's solar system, producing huge amounts of dust in the process. It's this unevenly distributed dust that might be preventing some of the star's light from reaching us, causing the rapid brightness changes. But that wouldn't explain the other pattern of long-term dimming over decades – comet dust dissipates in just a few months. This has led others to claim that the culprit might be megastructures built by advanced aliens to harvest the star's energy. If this technology was unevenly distributed around the star, it would cause sporadic dips as it orbited, and it would also block more light over time as the project was constructed

(explaining the longer-term fading).

This is a notion that Bodman rejects. "It's a fun idea, but it's been firmly eliminated," she says. She points to observations of the rapid dimming that show more light is blocked at the blue end of the spectrum than the red end. Blue light has a shorter wavelength, so this is exactly what you'd expect if it was being scattered by small dust grains (light is scattered most when it interacts with objects similar in size to its wavelength). However, analysis of the light spectrum linked to the longer-term dimming implicates larger dust grains. So we might, therefore, be looking at a complex cloud of different-sized dust grains blocking varying amounts of light as its orientation changes over time.

Yet the source of all that dust still remains a mystery. The long-term variations of Tabby's Star can be traced back to at least the 1890s. Dust shouldn't persist over such timescales, so it seems that some process is replenishing the dust as it's transported away by the outward pressure of the star's light. "There's no obvious explanation for what's going on," says Bodman.

Illustration of Tabby's Star, with the hypothetical cloud of gas that may explain the star's weird behaviour

“THIS HAS LED OTHERS TO CLAIM THAT THE CULPRIT MIGHT BE MEGASTRUCTURES BUILT BY ADVANCED ALIENS TO HARVEST THE STAR'S ENERGY”

NASA, WIKIPEDIA, UNIVERSITY OF ALASKA FAIRBANKS, GETTY IMAGES

FIVE MYSTERIES HERE ON EARTH

We're yet to figure out these enigmas in our very own backyard

1 BIGFIN SQUID

Many mysterious creatures skulk around the depths of our oceans, but none are as strange as the bigfin squid. To date, no adult specimen has ever been studied, but submersibles have filmed the animals in the Atlantic, Pacific and Indian Oceans. They look a bit like the aliens from *The War Of The Worlds* by HG Wells, with huge tentacles that can stretch up to eight metres long. These tentacles appear jointed, meaning these squid look like they have elbows.

2 STONE SPHERES OF COSTA RICA

Loggers clearing forests in Costa Rica in the 1930s found a bevy of large, almost perfectly spherical stones hidden among the trees. The largest weigh over 14 tonnes and are more than two metres in diameter. Known as the Diquís Spheres, it isn't clear how these sculptures were made or what purpose they served, but they are thought to have been created by a lost human civilisation that lived in the area around 1,000 years ago.

3 VOYNICH MANUSCRIPT

This 600-year-old book is written in a language that has never been seen before or since. Its 240 pages are littered with diagrams that are equally baffling. The unknown author has done such an incredible job of encoding it that its meaning is so far impenetrable, with

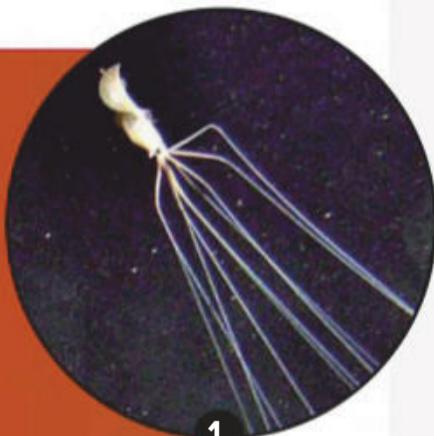
codebreakers trying for nearly a century to work it out. Last year, a study used artificial intelligence to deduce that it was originally written in Hebrew before being encoded, but many are unconvinced.

4 ARCTIC DINOSAURS

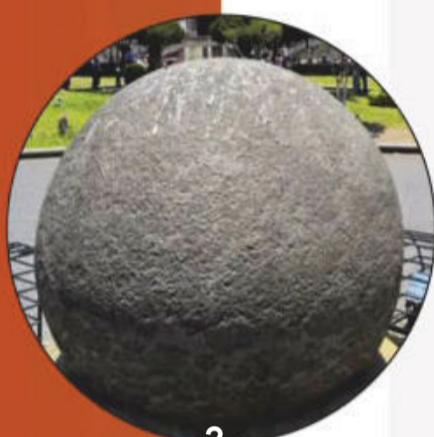
The cold, icy tundras of the Arctic are hardly a place you'd expect to find dinosaur fossils. After all, the reptiles were largely cold-blooded, and most of their fossils have been found in warm, temperate places. So the discovery of the remains of a nine-metre-long, duck-billed dinosaur in Alaska in 2015 was a real surprise. Palaeontologists now think that 13 species of dinosaur lived in Arctic conditions, causing us to rethink what we know about their physiology and habitats.

5 GENERAL ANAESTHETIC

In any given year, 1 in 20 of us will require an anaesthetic of some kind. It's mad, then, that we don't really know how general anaesthetic works. We know that it affects our brain cells' ability to communicate, and that consciousness relies on these cells firing correctly, but we don't understand how. One idea based on studies with flies and rats is that it prevents a protein called syntaxin1A from moving around brain cells in the normal way, but even that explanation is far from confirmed.



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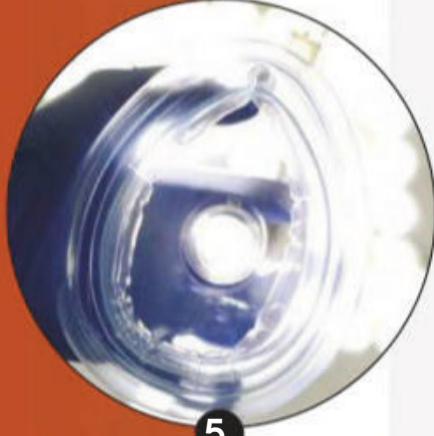
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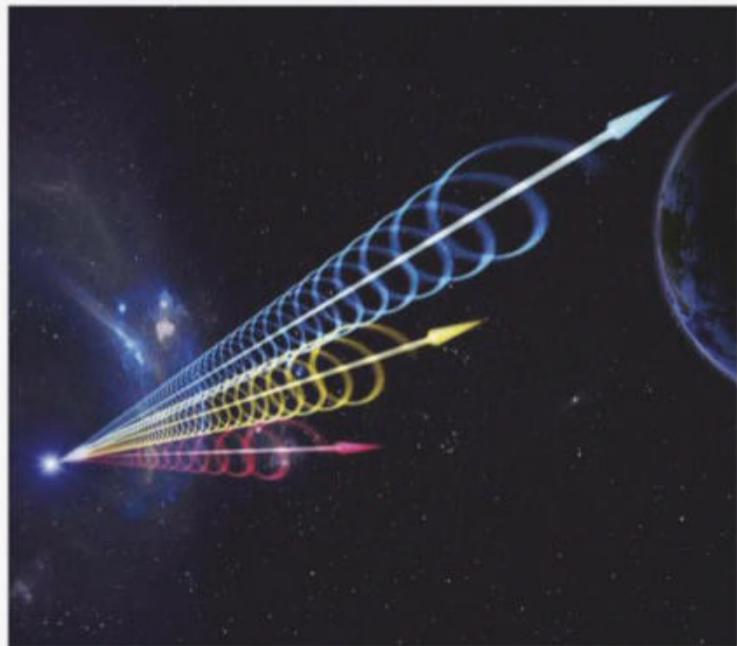
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FRB 121102

Fast radio bursts emit vast amounts of energy... but why?

Of all the things leaving astronomers scratching their heads, fast radio bursts (FRBs) are particularly vexing. As their name suggests, they are sudden, rapid chirps of radio waves, often lasting mere milliseconds. The first one was picked up by our radio telescopes in 2007, and we've been scrambling to try and explain them ever since.

These FRBs appear to be coming from outside the Milky Way, often hundreds of millions of light-years away. To be seen from such a distance, they must release as much energy in a fraction of a second as the Sun does in 80 years. Explanations range from colliding black holes to signals from extraterrestrial civilisations.

Yet before astronomers had managed to figure them out, the Universe threw us another curveball. A burst known as FRB 121102, emanating from a small galaxy three billion light-years away, was seen to repeat. On just one day in August 2017 it repeated a staggering 93 times, ruling out a single event as its cause – whatever triggered the burst had to be ongoing. So maybe FRBs are caused by rapidly rotating neutron stars, or material continuously falling into black holes.

Of course, FRB 121102 could be a red herring: there could be two separate causes of repeating and non-repeating FRBs. In October 2018, a new haul of 19 non-repeating FRBs was announced, including the closest and the brightest FRBs detected to date. Studying their properties should help us to pin down their home galaxies – and ultimately, we hope, the cataclysmic processes that are causing them.

ABOVE: This artist's impression shows the signal from a fast radio bursts blasting its way across space to Earth

RIGHT: Hoag's Object is completely unlike any other galaxy we know of

FAR RIGHT: Astronauts aboard the International Space Station have reported some strange effects when passing over a certain region of the South Atlantic Ocean

JINGCHUAN YU/BEIJING PLANETARIUM, NASA/HUBBLE SPACE TELESCOPE, GETTY

HOAG'S OBJECT

Nobody has any idea how this doughnut-like galaxy formed

We live in a flat, spiral galaxy known as the Milky Way. Other galaxies, called ellipticals, are shaped like rugby balls. Yet Hoag's Object appears to be neither. It has an older yellow core, surrounded by an outer ring of young blue stars. But in the middle: nothing. It's like something has swept away the spirals. There's no other galaxy in the Universe quite like it, and astronomers are stumped as to how it formed. It was spotted in 1950 by American astronomer Arthur Hoag, and perhaps the most feasible explanation offered so far is that, two to three billion years ago, a small galaxy sped through the larger disc-shaped galaxy, creating this unusual structure. But there's no sign of any galaxies nearby that might have served as the 'bullet', and such a collision would have sped up the core of Hoag's Object – whereas observations show that it spins slowly. To add to the conundrum, if you look closely at roughly the one o'clock position, there's a smaller version of the galaxy hidden within itself.





THE BERMUDA TRIANGLE OF SPACE

Colin Stuart is an astronomy speaker and author. His latest book is *How To Live In Space* (£16.99, Andre Deutsch).

Strange things happen when astronauts on the International Space Station pass through a certain region of space...

Imagine drifting off to sleep when, still with your eyes closed, you're suddenly startled by an intense flash of light. This is exactly what some astronauts have reported when passing through the South Atlantic Anomaly (SAA) – a region of the Earth's magnetic field also known as space's Bermuda Triangle. Scientists believe it is linked to the Van Allen radiation belts – two rings of charged particles trapped in our planet's magnetic grasp. Our magnetic field is not perfectly aligned to the rotation axis of the Earth, which means these Van Allen belts are tilted. This leads to an area 200km above the South Atlantic where these radiation belts come closest to the Earth's surface. When the International Space Station passes through this area, computers can stop working, and astronauts experience cosmic flashes – probably due to the radiation stimulating their retinas. Meanwhile, the Hubble space telescope is unable to take observations. Further study of the SAA will be crucial for the future of commercial space travel. **F**

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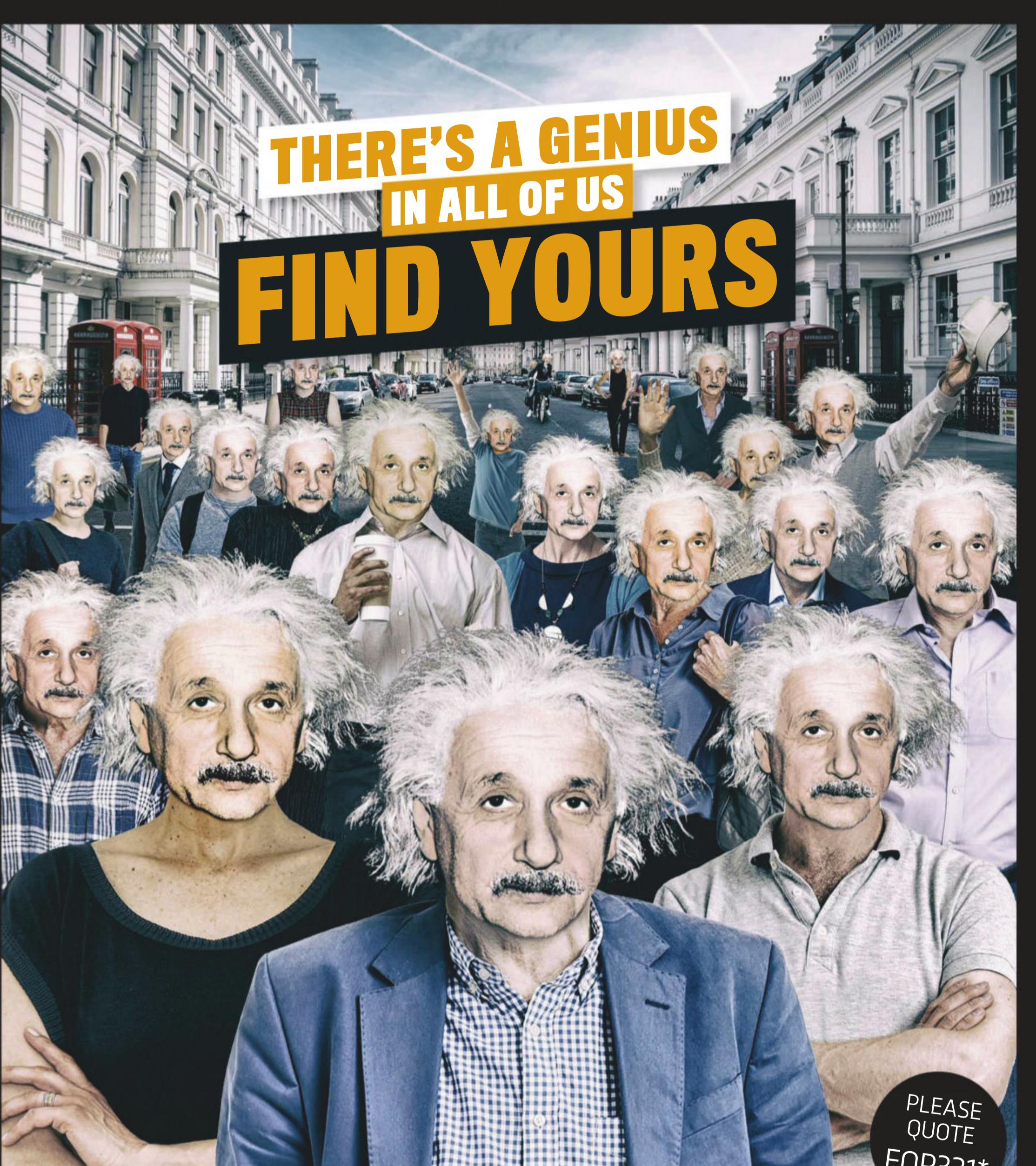
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NO MORE HEART ATTACKS

Can cutting-edge new treatments
and therapies put an end to
cardiovascular and circulatory
disease for good?

WORDS: SIMON CROMPTON

B

ack in 1976, a major medical breakthrough occurred. British researcher Michael Davies discovered that the cause of heart attacks was blood clots forming in the arteries on the surface of the heart. His finding no doubt saved the lives of many patients. Clot- and cholesterol-busting drugs, along with intricate artery-widening procedures, are now used routinely to prevent the artery blockages that deprive heart muscle of oxygen and cause heart attacks.

Fifty years ago, the chance of a UK citizen dying of heart disease – the term that describes the buildup of fatty ‘plaques’ in the blood vessels on the surface of the heart – was four times higher than today, yet heart disease and heart attacks are

“I think ending heart attacks is definitely something we can now work towards”

Cross-section of a coronary artery with a buildup of fatty plaques

still Western society’s biggest killer, taking the lives of one in seven men in the UK, and twice as many women as breast cancer. But now, new technologies and an explosion of understanding about what makes some people more susceptible to heart attacks is changing the game again. Researchers around the world now see the once pie-in-the-sky idea of ending heart attacks as a realistic, if ambitious, target.

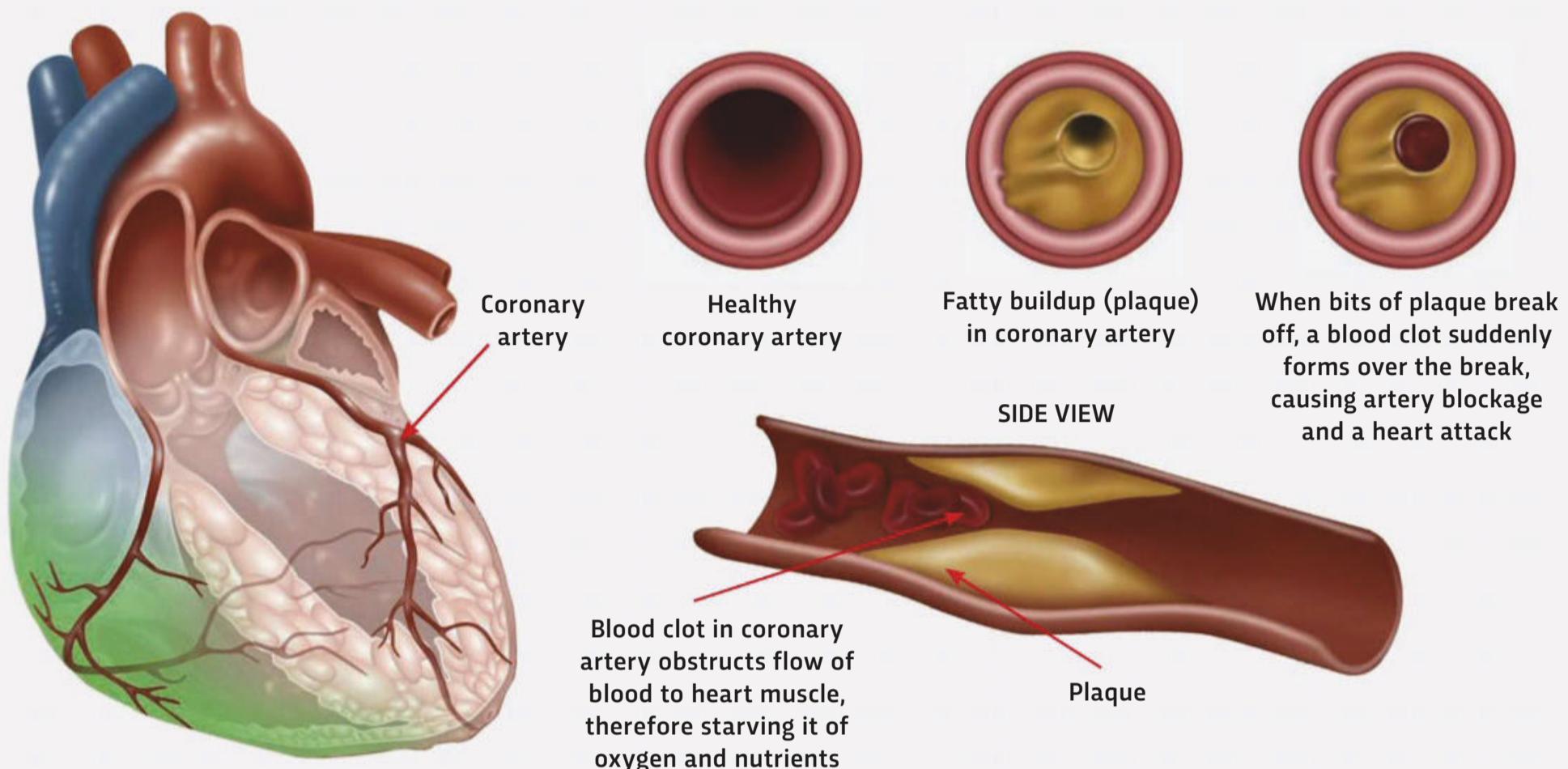
“I think ending heart attacks is definitely something we can now work towards,” says Prof Metin Avkiran, a molecular cardiologist at King’s College London and associate medical director of the British Heart Foundation. “We can definitely have a bigger impact.”

The objective of scientists is clear: to accurately predict who is most vulnerable to heart attacks, and then act early to prevent artery damage and blockage before it threatens lives. A range of game-changing developments are in the pipeline to stop heart disease in its tracks. These include early warning systems of heart attack using genetic data, heart scan analysis by artificial intelligence, and injectable molecular probes that seek out dangerous artery furring. Over the next few years, lab-manufactured antibodies will be available that block the proteins and inflammation which trigger heart attack. Even a vaccine to prevent heart attacks is on the cards.



WHAT HAPPENS DURING A HEART ATTACK?

The heart is covered with a network of blood vessels called 'coronary arteries'. These supply the heart muscle with oxygen- and nutrient-rich blood. If one or more of the coronary arteries becomes blocked, a heart attack may occur.



CALCULATE RISK

GPs and heart specialists can already predict your risk of heart disease by making calculations based on risk factors such as age, family history, cholesterol levels and blood pressure, and history of smoking and diabetes. But current risk calculations are crude. New understanding of genetics is changing that, moving on from calculations that rest on a vague 'family history' to accurate scores based on specific genetic traits. To date, researchers have identified 67 different sites in the DNA sequence (called variants) linked to increased heart attack risk, and many of them are inherited. The more variants you have, the higher your risk.

In October 2018, British scientists from the University of Cambridge and the University of Leicester, reported that their new Genomic Risk Score test was significantly more accurate than any other current means of predicting heart disease. The researchers based the test on a computer analysis of data from half a million people participating in the UK Biobank project. By crunching the correlation between 1.7 million genetic variants and health histories, artificial intelligence analysis came up with an algorithm that could accurately predict heart risk from a genetic profile.

The research – part of a global push to use machine learning to find patterns in big data to improve life expectancy – means it could soon

By measuring cholesterol levels in the blood, doctors can predict your risk of heart disease. But new genetic tests offer more accurate results

be possible for anyone (even children) to have a standard genotype test costing less than £50, and so have their heart disease risk assessed through the algorithm. Medical and lifestyle interventions could then be used to reduce the chances of those most at risk of having heart attacks later in life.

Other predictive tests are also being developed. This year, an algorithm for patients and doctors to use via an app was launched by the National Space Biomedical Research Institute in Texas, which works with NASA to reduce the tolls of human spaceflight on the body. Its new tool, named Astro-CHARM, combines traditional risk factors with a newly discovered heart risk indicator – coronary artery calcium – into a score predicting the likelihood of heart disease in the next 10 years.

FIND A MARKER

However, the holy grail for heart attack researchers has always been to find some sort of 'marker' that could indicate when the fatty (atherosclerotic) plaques lining heart arteries are in danger of breaking off – causing a blood clot in the heart artery, a blockage in blood flow, and then a heart attack. That is why Avkiran believes that some of the most exciting scientific developments in heart disease revolve around scanning techniques that will allow specialists to see exactly what is happening in the heart arteries. "Up to now, the ➤



► standard has been coronary angiography, which is essentially a sophisticated X-ray," Avkiran explains. "This allows you to see which arteries have atherosclerosis [furring], and how blocked the arteries are. But it's not very good for predicting heart attack risk. You need to be able to see which atherosclerotic lesions might rupture, causing a blood clot."

Scientists also know that arterial inflammation is a good indicator that atherosclerotic plaques are about to break, but accurately measuring it has been a problem. Now, researchers at the University of Oxford have found that this inflammation causes chemical changes in the fat that surrounds arteries. With this knowledge, they have developed a way of measuring fat changes using a computerised analysis of heart scans. A 10-year evaluation of the new technique, published in *The Lancet* in 2018, showed that fat values measured in this way were highly predictive of death from heart attack. An spin-off company is now developing a service to carry out fat analysis of heart CT scans from around the world within 24 hours.

EARLY WARNING SYSTEM

Another innovation to provide early warning of heart attacks involves injecting molecular probes into the bloodstream. The probes latch onto target molecules in the arteries, making underlying chemical processes in arteries visible and measurable on MRI scans of the heart region. Using this technique, Prof Rene Botnar from King's

ABOVE: Here, doctors examine a patient's heart arteries for blockages. With new ways to treat and detect heart problems, such surgeries may become a thing of the past

RIGHT: By measuring cholesterol levels in the blood, doctors can predict your risk of heart disease. But new genetic tests offer more accurate results

College London has found that the presence of a protein called tropoelastin provides a good indicator of plaque fragility, and that monitoring the protein could form the basis of future risk-prediction tests.

A similar technique has been pioneered by scientists at Imperial College London, who demonstrated in animal models that another marker of plaque vulnerability – oxidised 'bad' cholesterol (LDL) – could be made visible on CT scans. They did it by creating an artificial antibody to seek out and bind with oxidised LDL, and linking the antibody to a fluorescent molecular marker. They are now researching the technique on humans, and believe it may also have potential as a means of delivering drugs directly to their arterial targets.

"There are many exciting new approaches to prediction, and I think it's going to be a combination of these that help people at different stages of their lives to assess risk, not just a single one that changes

"Techniques will allow heart specialists to see exactly what's happening in the heart arteries"

HOW TO LOWER YOUR RISK OF HAVING A HEART ATTACK

“everything,” explains Avkiran. Identifying your risk of heart attack is one thing. Preventing it is another. And it is artificial versions of antibodies – the proteins produced by the immune system to seek out and neutralise invaders – that are presenting some of the most exciting prospects.

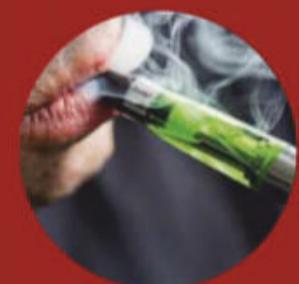
New drugs created from artificial antibodies are indicating they may overtake the success of statins, which have transformed the survival odds of people with heart disease over recent years. Statins are medicines that are prescribed to patients to reduce cholesterol in the bloodstream, slowing the rate of plaque build-up. Already available are new types of cholesterol-busting drug called PCSK9 inhibitors, which are composed of artificial antibodies that target and inactivate a protein in the liver. This in turn lowers the amount of harmful LDL cholesterol circulating in the bloodstream.

But researchers have now discovered a new class of antibody drug that slashes heart attack risk by decreasing inflammation in the arteries. A massive trial across 40 countries of one of these drugs, canakinumab, was reported last year. It found that the drug reduces the risk of heart attack by 24 per cent in people with heart disease. Now there is evidence that targeting inflammation significantly improves outcome for people ➤



Don't smoke or vape

It's widely known that smoking increases your risk of heart disease. But new research from the University of California, based on a survey of 70,000 people, indicates that daily use of e-cigarettes can also increase the odds of a heart attack.



Avoid traffic

Transport and industrial pollution are harmful for the same reason as smoking: microparticles enter the bloodstream, the immune system activates against them, and this causes damaging inflammation in the arteries. But a new study, published in the *European Heart Journal*, indicates that traffic noise also raises heart attack risk.



Eat a balanced diet

You don't have to cut out meat and dairy to have a heart-healthy diet, according to a new study published in *The Lancet*. The researchers said a healthy diet should contain plenty of fruits, veg, fish and legumes, as well as moderate amounts of unprocessed meats and dairy. The British Heart Foundation says that eating meat and dairy in moderation is fine.



Avoid processed meat

The consensus is that processed meat (like bacon, ham and salami) is not good for your heart. A major review of research in 2010 concluded that daily servings of processed meat was associated with a 42 per cent higher risk of coronary heart disease.



Relax

A new study in *The Lancet* has shown that, under stress, the amygdala in the brain signals the blood marrow to release a type of blood cell that increases levels of inflammation in the arteries.



Cut down on alcohol

New research has found that young adults who frequently binge drink are more likely to have heart attack risk factors – raised blood pressure, cholesterol and blood sugar – at a younger age than non-binge drinkers. Research from University College London shows that the arteries of teenagers who drink alcohol and smoke are already beginning to stiffen by age 17.



Lose weight

Being overweight can raise your blood pressure and cholesterol, and increase the likelihood you developing diabetes – all of which are risk factors for heart disease.



► with cardiovascular disease, the way is open for a whole new front of attack.

The new antibody-based drugs in the pipeline will be expensive. But at the same time, more accurate prediction of those most at risk means that the drugs will be targeted at those most in need. One of the most intriguing discoveries about how antibodies can help beat heart disease comes from research at Imperial College London, led by Dr Ramzi Khamis, clinical senior lecturer in cardiology. It raises the possibility of a cure, as well as accurate prediction.

Khamis's focus has been on naturally occurring antibodies. All of us have antibodies that seek out harmful oxidised LDL, and take it away to be dealt with by the liver. Two types of antibody, called IgG and IgM autoantibodies, seem to be particularly good at tackling oxidised LDL.

It seems that some of us have greater numbers of these antibodies than others. Working with scientists from the Netherlands and Sweden, Khamis and his team studied 100,000 people with high blood pressure, and found that those who

had heart attacks and the most unstable plaques had the lowest levels of these antibodies. In fact, those with high levels of the antibody had 70 per cent less chance of developing heart disease over five years.

"We found the antibodies provided a massive level of protection," says Khamis. "Not only might measuring these antibody levels help us assess heart attack risk, but we're also looking to explore whether we can use the antibodies therapeutically." Antibody therapies might be used to boost the immune system's ability to fight oxidised LDL – and might even eventually yield a vaccine to reduce heart attack risk.

"That may be 10 years ahead, but there is that potential," says Khamis. "But what we're certainly demonstrating is that the role of the immune system in preventing heart attack is much bigger than previously thought." □

Simon Crompton is a science journalist and former health editor for both *The Times* and *The Daily Telegraph*.

UK HEART DISEASE IN NUMBERS

420

People lose their lives to heart disease every day

The annual healthcare cost of heart and circulatory disease in the UK is £9bn



The premature heart attack death rate for Manchester is four times higher than rural mid-Suffolk



of all deaths are due to heart and circulatory disease



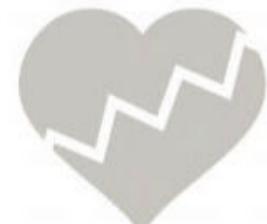
In the UK, around seven million people live with heart and circulatory diseases

People with high blood pressure are up to three times more likely to develop heart disease or have a stroke



Since 1961

the death rate from heart and circulatory disease has declined by more than three-quarters



There are 2.3 million people in the UK living with coronary heart disease

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THE REAL SCHRÖDINGER'S CAT

In 1935, Erwin Schrödinger created his famous thought experiment involving a cat that is both dead and alive to illustrate a perceived flaw in the emerging field of quantum theory. Nearly a century later, the idea is not proving as absurd as he originally intended...

WORDS: BRIAN CLEGG

Back in 1935, Albert Einstein and colleagues hypothesised that quantum theory predicted a remote linkage between particles, called quantum entanglement. Einstein took an instant dislike to the idea, calling it "spooky action at a distance". He hoped that the existence of quantum entanglement meant that quantum theory, which he wasn't too keen on to begin with, was somehow flawed, or not yet fully understood.

Quantum entanglement is a bizarre offshoot of quantum theory that says certain properties of a pair of particles become linked together in such a way

that if you measure the value of one of them, then you instantaneously know the state of the other, even if they are separated by cosmic distances. Weird, eh? Sadly for Einstein, quantum entanglement has been demonstrated to be true many times, but so far only on a subatomic level.

Quantum theory describes the workings of the Universe's smallest known components, predicting the behaviour of electrons and atoms, molecules and photons of light. And it does so incredibly well: eminent physicist Richard Feynman pointed out that quantum theory is so accurate it's like predicting the distance between New York and Los





• Angeles to the width of a human hair. Yet quantum particles behave totally unlike everyday objects on a more human scale.

TOO WEIRD FOR EINSTEIN

One of the key tenets underlying quantum theory is the idea that a particle can be in more than one place at any given time. Oddly, when not interacting with the world around them, or having their positions specifically measured, quantum particles don't have a specific location. Instead, all that exists is a collection of probabilities of where the particle could be at any given time – a so-called superposition of states. It is this phenomenon that leads to Schrödinger's cat (see opposite page) being both alive and dead.

This gives us a puzzling distinction between everyday macroscopic objects, which obey the predictable precision of 'classical physics', and the microscopic world of tiny objects – 'quantum physics' – where probability rules. Einstein was so appalled at this idea it led him to say: "I would rather be a cobbler, or even an employee in a gaming house, than a physicist."

When Einstein raised his objections to entanglement in the 1930s, it wasn't possible to

"Einstein was so appalled at [entanglement] it led him to say: 'I would rather be a cobbler, or even an employee in a gaming house, than a physicist'"

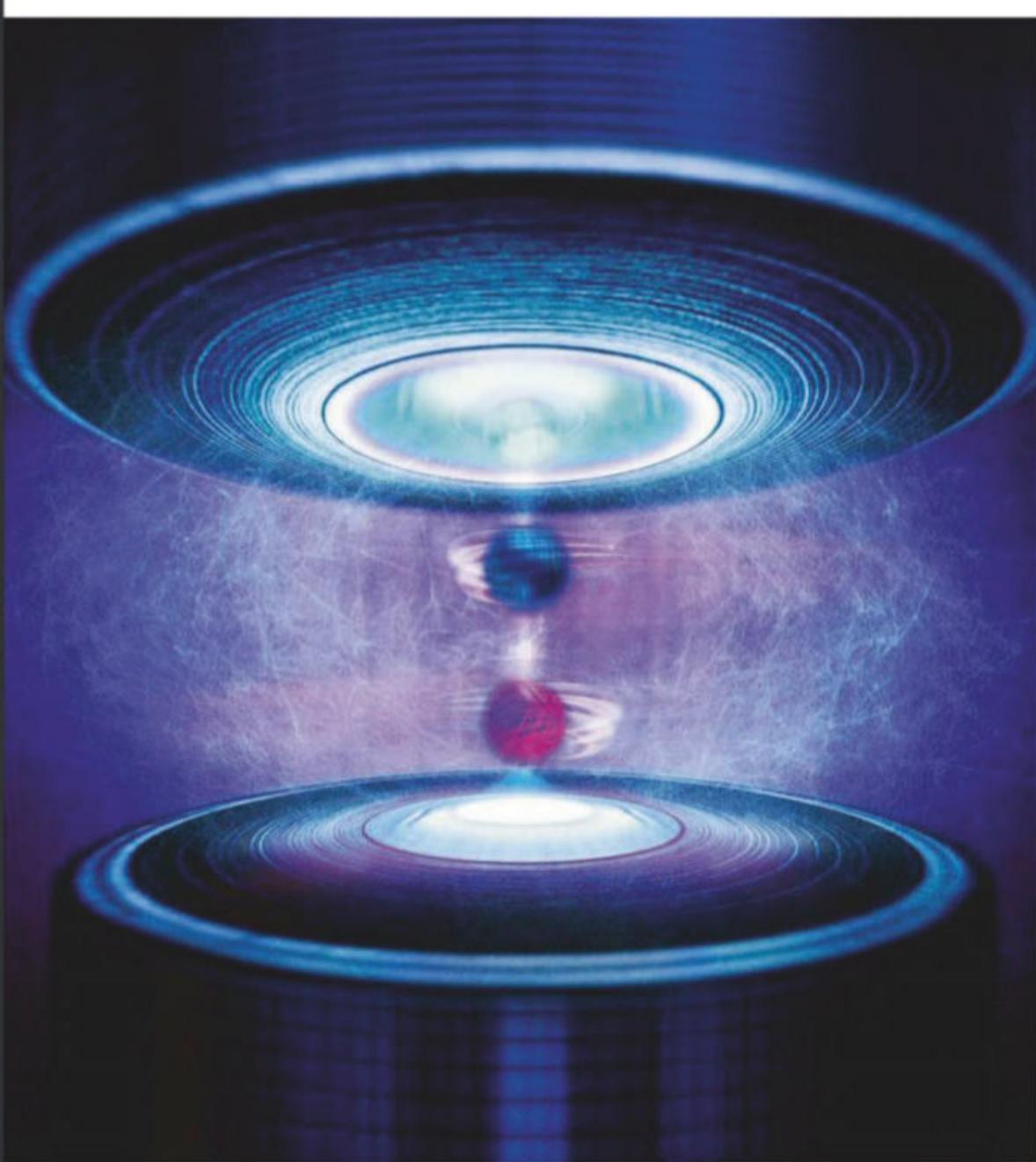
This illustration represents 'spin', which is one of the properties of subatomic particles

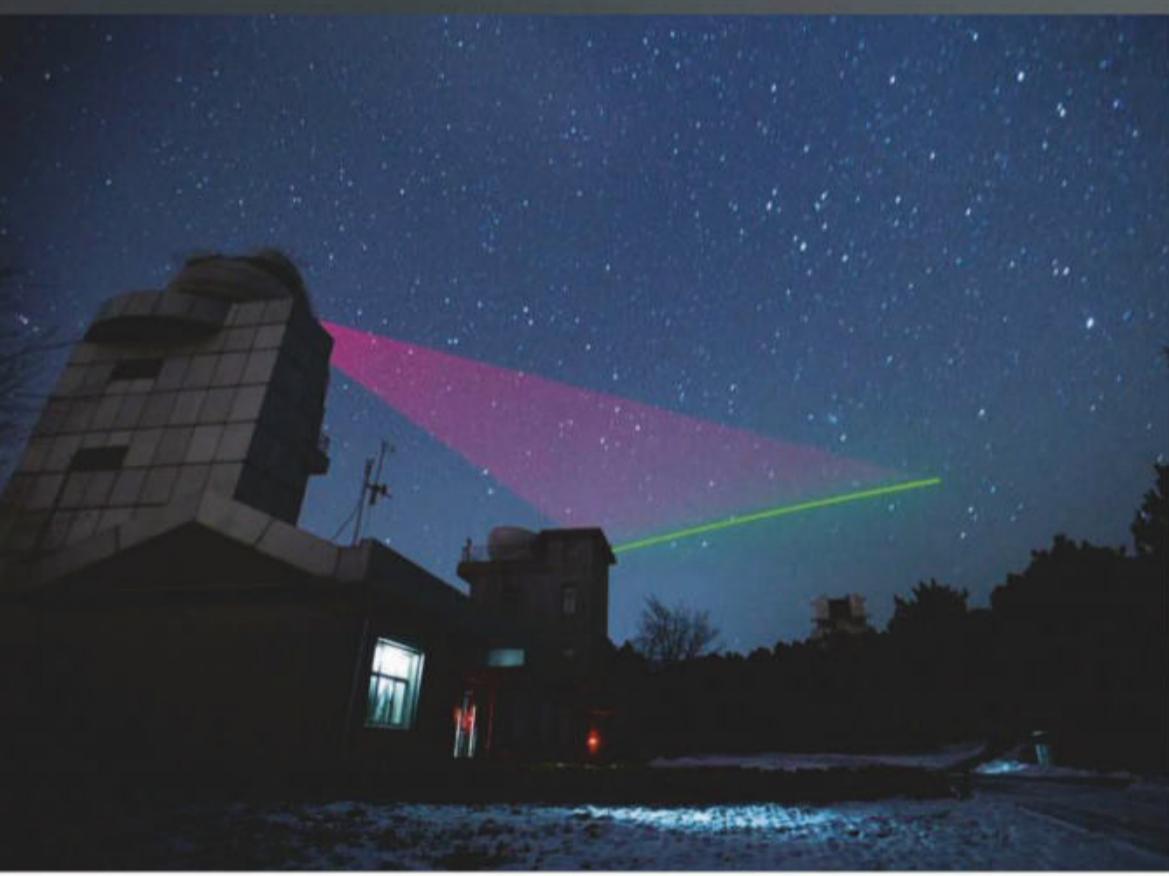
experimentally verify it. But by the 1970s it became feasible, and successful entanglement experiments have been run many times since. There are even several practical applications of entanglement. One is quantum encryption. It takes inspiration from an idea by the American banker and cryptographer Frank Miller, who was working on the creation of an unbreakable cipher called a 'one-time pad' around 100 years ago. His idea was to give both sender and receiver a key made up of random values, but the approach was not 100 per cent secure because this key would have to be sent to both sender and receiver and so could be intercepted. However, as quantum entanglement automatically provides random values even at widely separated locations, and also makes it possible to check whether particles have remained entangled, it would be impossible for a third party to read the random key before the particles reach their destinations. Chinese researchers have tested this principle, sending entangled photons to locations 1,200 kilometres apart.

TELEPORTATION DEVICE

Quantum entanglement also makes quantum teleportation possible. Without entanglement it's not possible to copy a quantum particle, because observing it will change the particle's properties into a specific state. But quantum entanglement can transfer the state from one particle to another without altering it. This is like a small-scale version of a *Star Trek* transporter, though real teleportation makes a remote copy, scrambling the original, rather than moving it.

In practice, using teleportation on people would be impractical as they contain too many atoms. But the process can transfer quantum information from place to place, which is essential when building quantum computers. In standard computing, bits have values of 0 or 1. With quantum computing, bits are replaced with qubits, combining probabilities of 0 and 1 simultaneously, making it possible for special programs to run far faster than on a conventional computer.





China's quantum satellite Micius has sent entangled photons (particles of light) from space to ground stations on Earth

Even outside of the lab, quantum phenomena are occurring all of the time. Any interaction between matter and other matter or light is a quantum process. All electronic devices rely on quantum phenomena, and even the Sun wouldn't work were it not for the probabilistic nature of the location of quantum particles enabling hydrogen nuclei to get close enough together to fuse and produce energy. There is also increasing awareness of quantum processes in biology. For example, photosynthesis, used by plants to generate energy from light, seems to use quantum effects to channel energy to the appropriate part of the plant. Entanglement also may enable pigeons and robins to navigate. These birds detect the Earth's magnetic field, apparently due to quantum entanglement in their eyes. Light coming into the eye boosts the energy of electrons. A property of the electrons called 'spin' is then influenced by tiny variations in the Earth's magnetic field, and it is thought that quantum entanglement makes it possible for the bird to build a picture by linking different electrons.

SCALING UP

But can quantum phenomena apply to objects bigger than tiny atoms or molecules? The answer appears to be yes. Dr Simon Gröblacher of Delft University of Technology and his colleagues have entangled two microscopic silicon bars. These bars measure $10 \times 1 \times 0.25$ millionths of a metre, making them finer than a human hair. They have tiny pockets inside them that absorb energy from laser light which causes them to vibrate. The laser light is set up in such a way that the vibrational states of the bars become linked via quantum entanglement. This is highly unusual. Usually in an object of this size, interaction between different atoms within the object, and with any atoms it comes into contact with, destroys entanglement in a process known

WHAT IS SCHRÖDINGER'S CAT?

The Schrödinger's cat thought experiment demonstrates the strange nature of quantum superposition. A cat is placed in a box with a vial of poison, which will be automatically smashed if a radioactive particle decays. Radioactive decay is one of the probability-driven aspects of quantum physics. We can't say when a given particle will decay, we only know the probability of it decaying in a certain period. After some time has elapsed, an unobserved particle will be in a superposition of decayed and not decayed states. All that exists before measurement (someone looking inside the box) is the probabilities. But since the life of the cat depends on the state of the particle, does this mean the kitty is

simultaneously dead and alive?

In reality, we could never witness the cat being both alive and dead – as soon as we look in the box, the cat will be in just one state. And the practicalities of the experiment don't even allow for this. For the detector to be able to release the poison it would have to interact with the particle, forcing it to be either decayed or not decayed.

Despite its limitations, Schrödinger's cat gives us a feel for the weirdness of superposition, and while such a test wouldn't be possible with a complex organism like a cat, proposed experiments with a tardigrade could bring an aspect of the Schrödinger's cat experiment closer to reality.

Schrödinger's cat: dead and alive at the same time, until it is 'fixed' into one of these states by someone observing it



TARDIGRADES: THE WORLD'S TOUGHEST ANIMALS



1 Tardigrades, also known as water bears or moss piglets, are a group of eight-legged animals. They are about 0.5mm long, and can be found around the world in a wide range of environments.

2 Tardigrade means 'slow paced'. It was originally an adjective applied to tortoises, but since 1800 it has been the name of these microscopic creatures.

3 Tardigrades can cope with extreme high and low temperatures that would kill other organisms. Some species can survive exposure to -272.15°C.

4 If a tardigrade is dehydrated and loses up to 99 per cent of its water content, its living processes can be near-suspended for several years before being brought back to life.

5 In 2007, dehydrated tardigrades were taken up into orbit and exposed to the vacuum and radiation of space for 10 days. On return to Earth, over two-thirds of them were successfully revived. Many died relatively soon after, but were still able to reproduce before they passed away.

6 Inside the cells of dehydrated tardigrades, a protein replaces the water. This forms a glass-like substance that keeps the cell structures intact.

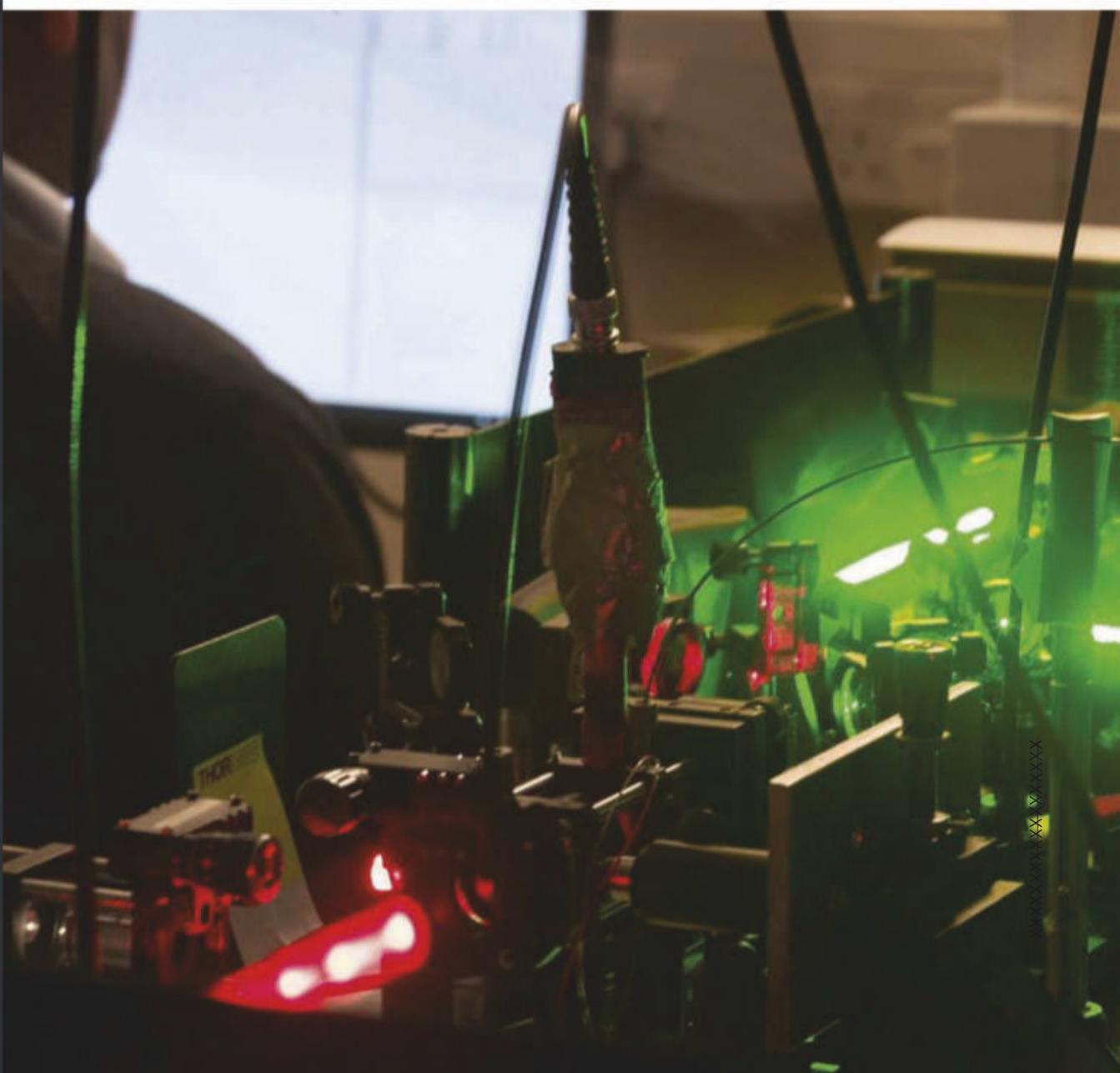
7 Tardigrades are among the few animals to have lived through all of our planet's big five extinction events.

A quantum optics setup at the University of Oxford with laser beams passing through a series of elements

as 'decoherence'. So if it is possible to entangle a pair of silicon bars, how big could we go? Could we entangle living organisms?

Quantum biology is still a young field, but inspired by experiments such as Gröblacher's, some scientists are devising experiments to use quantum effects to produce superpositions and entanglement in living organisms. One group believes that this has already happened. In 2016, Dr David Coles of the University of Sheffield and his colleagues sent light bouncing across a narrow gap between two mirrors, through green sulphur bacteria. The experiment was devised to study photosynthesis, but when subsequently analysing the data, a group led by quantum physicist Dr Chiara Marletto at the University of Oxford discovered evidence that molecules inside the green sulphur bacteria had become entangled with the photons of light.

They are not 100 per cent certain of the effect, as proving entanglement would require measurements of the photons and the bacteria independently, and this wasn't possible in their particular experiment. Marletto admits that dealing with living organisms is far harder than quantum particles. "In quantum biology the molecules are very messy, and it is hard to perform accurate measurements," she says. "What one would have to do is to isolate a single biomolecule [a molecule in a biological organism] within the bacterium and demonstrate that it is entangled with light," she says.



“Entangling living bacteria is a first step towards assessing the feasibility of implementing teleportation in bacteria”

INTO THE REAL WORLD

But if such entanglement does occur, it could possibly be a survival mechanism that the bacteria use to harvest the scarce light in the deep oceans. And if entanglement were proven, it would open up a wealth of further possibilities.

“There has been a long-standing debate about whether quantum theory applies to all scales. The experiment shows that biomolecules in living entities are perfectly capable of displaying quantum effects by being entangled with light. The remarkable thing also was that the bacteria were alive throughout the experiment,” says Marletto.

To investigate the phenomenon further, Dr Tristan Farrow, one of Marletto’s colleagues, has proposed a new study to entangle a quantum property in a pair of bacteria. Although initially limited to a single property, Farrow believes the experiment could be taken further. “Entangling living bacteria is a first step towards assessing the feasibility of implementing teleportation in bacteria,” he says. “Big, hot and messy systems such as biomolecules, never mind living organisms, have long been thought to be hostile environments for quantum states to survive for any meaningful length of time. We don’t know whether this is always true, or whether certain sub-structures inside these complex molecules can shield quantum states from the hostile environment.”

And there could be practical applications, too. “Bio-inspired quantum computing is an applied aspect of our research, aiming to reverse-engineer artificial structures inspired by biology,” says Farrow. “A prime example would be an artificial leaf to harvest light energy with extreme efficiency inspired by how certain photosynthetic molecules might use quantum superpositions to transport energy captured from sunlight.”

Gröblacher is also interested in experiments involving living creatures. He is currently working



Subatomic particles can become entangled. Even if they are separated across great distances, a change or measurement to one particle will affect the other

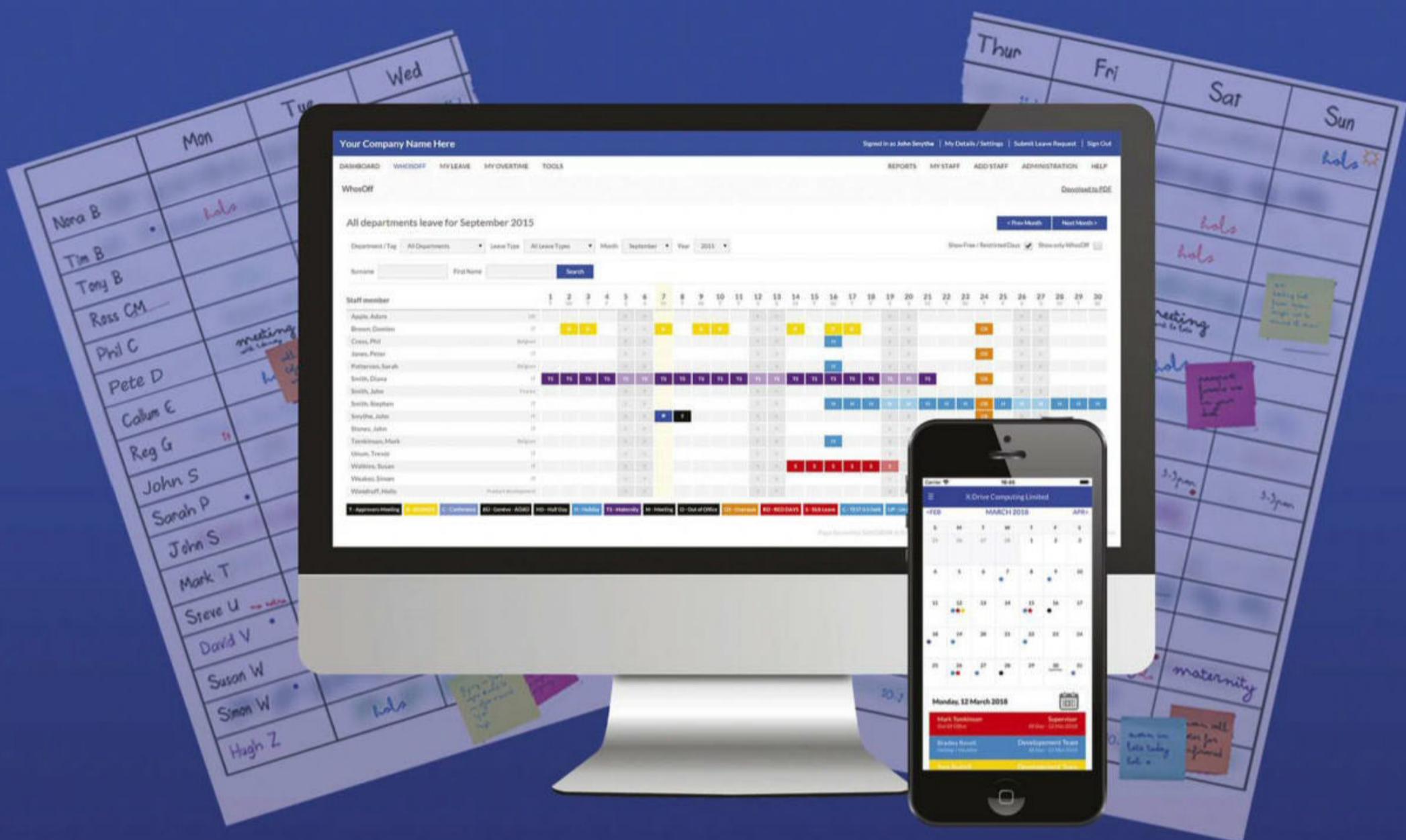
on putting a sheet of nitride into a superposition of states. By using a laser, it is theoretically possible to get a barely visible membrane of silicon nitride measuring around one millimetre across into a superposition of vibrations with two different amplitudes. The amplitude is related to the amount of energy carried by a wave, and is the measurement from the undisturbed position to the peak of the wave. If you apply more force, the peak – and therefore amplitude – increase. Gröblacher reckons they are within a couple of years of achieving this superposition of vibrations.

“A superposition state of these membranes would allow us to demonstrate that objects that are visible to the naked eye still behave quantum, and we can really test decoherence – the transition between classical and quantum mechanics,” he says.

He then hopes to extend the experiment by placing tiny living organisms called tardigrades (see opposite page) onto the membrane of silicon nitride, putting them into superposition too. One of the remarkable abilities of tardigrades is their ability to survive being dehydrated. The tardigrades would be in their dehydrated state during the experiment so that there would be no impact on their biology. If successful, Gröblacher’s tardigrades would be the closest we’ve come to seeing a living creature in two simultaneous states – a real-life Schrödinger’s cat. ♦

Brian Clegg is a freelance author who has written over 30 science books. His latest is *The Graphene Revolution* (£8.99, Icon Books).

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A man is shown from the waist up, wearing a blue tank top and a metabolic gas analysis mask with a blue tube. He is on a stationary bike, with his hands gripping the handlebars. The background is a blurred indoor setting.

THE NEW SCIENCE OF EXERCISE

Gone are the days of sweating your way through an hour-long aerobics class.

According to the latest research, it could be possible to get fit and boost your health in a matter of minutes

WORDS: JAMIE MILLAR

Few forms of exercise have been as highly and intensely researched – or publicised – in recent years as high-intensity interval training (HIIT). In 2018, HIIT headed up the yearly survey of worldwide fitness trends by the American College of Sports Medicine (ACSM). It has remained in the top five since it entered at the top spot in 2014. HIIT is proving to be an enduring hit.

True, HIIT is down to number three in the ACSM's 2019 chart, behind wearable tech (number one) and group training (number two). But if you've been to a fitness class lately, then there's a strong chance that you did HIIT, even if you didn't realise it at the time. "The best way to explain it is repeated bouts of high intensity followed by a bout of recovery," says Tom Cowan, an exercise physiologist at the Centre for Human Health and Performance (CHHP) on London's Harley Street.

WHAT IS HIIT AND WHAT DOES IT DO?

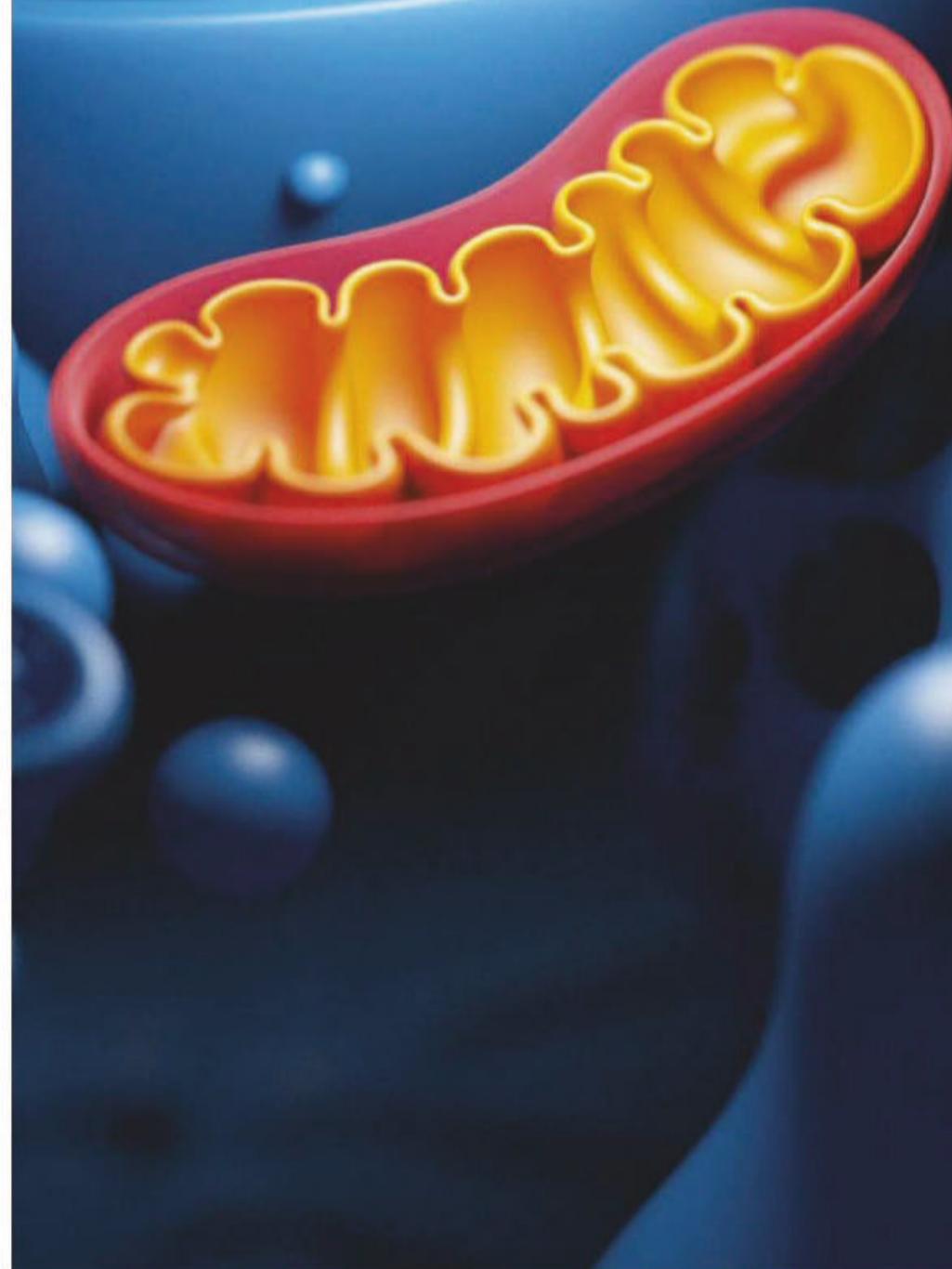
According to the ACSM, high-intensity intervals are exercises that you typically perform at 80 to 95 per cent of your maximum heart rate, for anywhere from five seconds to eight minutes. Generally, the shorter the interval, the higher the intensity and vice versa. The work intervals are alternated with periods of complete rest or active recovery performed at 40 to 50 per cent of your maximum heart rate, lasting for the same duration (although they can be longer or even shorter depending on your fitness).

HIIT is highly adaptable for varying fitness levels and goals, which partly explains its popularity among everybody from elite athletes to cardiac rehab patients. It can be performed on gym equipment such as static bikes, treadmills and rowing machines (cardio HIIT), or via exercises such as press-ups (bodyweight HIIT).

Its popularity is welcome news, because HIIT has been shown to improve fitness, cardiovascular health, cholesterol profiles and insulin sensitivity, which helps stabilise blood glucose or sugar levels – of particular significance to diabetics. HIIT also reduces fat – both abdominal and the deep, visceral kind that engulfs your inner organs – while maintaining muscle mass or, in less active individuals, increasing it.

More strikingly, according to a small study in *Cell Metabolism* in 2017, HIIT effectively halts ageing at the cellular level, by increasing

the production of proteins for the mitochondria, your cells' energy-releasing powerhouses, which otherwise deteriorates over the years. Other forms of exercise such as strength training do likewise, but HIIT is more effective. The study also stated that muscle cells, like those in the brain and heart, wear out and aren't easily replaced, so if exercise prevents deterioration of mitochondria in muscle cells, or even restores them, then it likely does so in other tissues too. Similarly, HIIT beats continuous moderate-intensity exercise when it comes to releasing brain-derived neurotrophic factor (BDNF), a protein that protects nerve cells. This promotes plasticity (the forming of new connections, which aids learning and memory) and may even help regulate eating, drinking and body weight.



ABOVE: HIIT is said to improve the function of the mitochondria in your cells (the orange cross-section in this illustration), so they get better at converting oxygen and nutrients into fuel for your muscles



“According to a small study... HIIT effectively halts ageing at the cellular level, by increasing the production of proteins for the mitochondria”

ABOVE CENTRE: Dr Izumi Tabata (in the lab coat) has lent his name to a HIIT protocol that produces greater improvements in fitness than longer bouts of moderate exercise

ABOVE RIGHT: Finnish middle-distance runner Paavo Nurmi incorporated high-intensity interval training into his regime. He broke 22 world records and won nine Olympic gold medals during his career

GETTYX2

Perhaps HIIT's biggest selling point is its efficiency: a workout can last up to an hour, but it can also be completed in 20 minutes or less. Tabata, one of the most well-known HIIT protocols, consists of 20 seconds of work followed by 10 seconds of rest, repeated eight times for a total of just four minutes, not counting the warm-up and cool-down.

In a famous 1996 study by Tabata's namesake Dr Izumi Tabata, people who performed the four-minute protocol on an exercise bike five times a week improved their VO_{2max} – the uppermost rate at which your body can utilise oxygen for energy during exercise – by 15 per cent after six weeks. People who exercised for

60 minutes at moderate intensity five times a week only improved their VO_{2max} by a mere 10 per cent. Moreover, the Tabata group boosted their anaerobic capacity – the body's ability to produce energy without oxygen, used for short bursts of hard effort – by 28 per cent. The continuous exercise group's stayed the same.

THE REWARDS

It sounds like the fanciful stuff of home shopping channel infomercials, but HIIT is legit – even *The One-Minute Workout*, a book published in 2017. The workout (three 20-second intervals interspersed with one to two minutes of recovery) improved the fitness of people who performed it three times a week for 12 weeks, just as much as those who did traditional cardio ➤



for 50 minutes three times a week. It was devised by Dr Martin Gibala of Canada's McMaster University, who is one of the leading researchers into HIIT. "It's not a fad," confirms CHHP's Cowan. "It's completely got the backing, and there are more and more studies coming out."

While it might seem like a recent trend, HIIT isn't a new concept. It's been employed for at least a century by athletes. For example, legendary Finnish distance runner Paavo Nurmi set a 1,500m world record in 1924 by running repeated hard sprints in training. What is new is the scientific research, which began in earnest at the start of this century. HIIT has been heralded as a powerful weapon in the fight against unhealthy lifestyle-related diseases such as obesity and type 2 diabetes. And if nothing else, it's convenient: one of the most-cited obstacles to physical activity is lack of time.

"Also, a lot of cool, fashionable gyms and studios that are all glammed-up with music – not just in London but there are plenty there – follow a HIIT-based approach, with circuit-type or spin classes," says Cowan. "That's quite appealing to a lot of people, as opposed to having to jog for an hour in the park, which is a bit more monotonous."

This variety is what makes HIIT so impactful. "Because you get the rest between [every work interval], you can spend more time doing each one at a higher intensity, which you couldn't sustain otherwise," says Cowan. "If you do 10 two-minute work intervals, you've actually managed 20 minutes."

Ramping up the intensity forces your body to tap into its anaerobic system for energy, because it can't supply the oxygen required to work aerobically quickly enough; in the recovery intervals, your body reverts to its aerobic system. As the session goes on, your body relies less on the anaerobic system, because quick-release energy sources of phosphocreatine and glycogen (glucose stored in your muscles) become depleted. Your body will therefore start to rely more on the aerobic system, which releases energy more sustainably but slowly from fat. You won't be able to achieve quite as high an intensity as you could at the start, but the upshot is a double whammy. "You're essentially using a mixture of the anaerobic and aerobic systems, so you get an improvement in both," says Cowan.

Respiring anaerobically has knock-on effects. "It's like when you're puffing and panting after running for a bus, you're trying to repay the oxygen deficit," says Cowan. This excess post-exercise oxygen consumption, which is more pronounced with HIIT than continuous exercise, burns a further 6 to 15 per cent more calories as your body replenishes itself. Lactic acid and hydrogen ions produced during anaerobic respiration have to be cleared, as do hormones such as adrenaline; your body temperature and heart rate also need bringing back down: "All of those things increase the workload following

ABOVE: There is growing evidence that repeated, short bouts of intensive exercise is better at burning off the fat that sits around your abdomen and internal organs than longer, more sustained bouts of exercise

HIIT AT HOME

Get your body moving after a gluttonous festive season with our workout

This HIIT workout, courtesy of Tom Cowan, an exercise physiologist at the Centre for Human Health and Performance, can be performed at home. You don't need any special equipment, and you can increase or reduce the intensity of the exercises, depending on your level of fitness. Nevertheless, a good degree of conditioning is a prerequisite, he warns: "If you're new to HIIT, have been physically inactive, have an injury, are taking medication or have a health condition, then consult your doctor before doing these exercises."

WARM UP

It's important to spend five to 10 minutes gradually raising your heart rate. This could be walking, progressing to a light jog or going up stairs. Then perform some mobility exercises such as light squats and lunges, wall presses, torso rotations and arm swings.



CONSULT A
DOCTOR BEFORE
UNDERTAKING
ANY NEW EXERCISE
REGIMES

5 to 10 minutes

WORKOUT

Perform each of the following exercises for 30 seconds, followed by 30 seconds of recovery (walking or standing), before moving onto the next exercise. Complete three rounds of the routine in total:

BURPEES
(Lower intensity: toe-touch squat jumps)



30 seconds
RECOVERY 30 SECONDS

JUMPING LUNGES
(Lower intensity: alternating reverse lunges)



30 seconds
RECOVERY 30 SECONDS

30 seconds
RECOVERY 30 SECONDS

HIGH-KNEE RUNNING ON THE SPOT
(Lower intensity: march on the spot)

30 seconds
RECOVERY 30 SECONDS



PRESS-UPS
(Lower intensity: knees on the floor or hands on a step)

JUMPING JACKS



30 seconds

MOUNTAIN CLIMBERS



30 seconds

HIGHER/LOWER

Increase/reduce the tempo to perform more/fewer repetitions of the exercises in 30 seconds. Reduce/increase the length of the recovery intervals in between each exercise. Increase/reduce the total number of rounds of the full routine you complete.

COOL DOWN

Spend five to 10 minutes bringing your pulse back to its resting rate. Try doing the warm-up in reverse, decreasing in intensity. Finish by stretching the muscles that you've worked.

► the exercise.” Workload is one of the reasons why we’re not all doing HIIT all the time: you have to recover adequately between sessions. “Three sessions a week is probably okay but it’s not something that you’re recommended to do every day,” says Cowan.

If you don’t sufficiently replenish your glycogen after HIIT with quality carbohydrate sources, you won’t be able to achieve a high-enough intensity in subsequent sessions. “And, actually, diet in combination with exercise is what’s really going to help with fat loss,” says Cowan. “It’s no good training like this and eating rubbish.” Bodyweight HIIT meanwhile will, like other forms of resistance training, cause micro-tears in your muscle that need time and protein intake to repair. Research recommends 60g of carbs with between 10g and 20g of protein post-exercise to optimise glycogen synthesis.

BELOW: Press-ups are an effective bodyweight exercise for HIIT sessions

BELOW RIGHT: The release of brain-derived neurotrophic factor (BDNF), which protects nerve cells, is boosted by HIIT training

THE RISKS

You can have too much of a good thing, though especially if you’re a beginner and don’t have a qualified professional on hand to ensure that the intensity isn’t too high for you. A study in the *Federation Of American Societies For Experimental Biology Journal* showed that interval training can actually halve the function of mitochondria

in newcomers. And just one overzealous spin class can be enough to trigger rhabdomyolysis, where muscle fibres break down and leak into the bloodstream, which can in turn lead to kidney failure.

HIIT is considered safe for most if correctly prescribed, although it may raise coronary risk for sedentary people. But Cowan stresses that you should consult a doctor if you’re new to exercise or have any kind of clinical diagnosis. He also recommends starting off with six weeks of continuous, lower-intensity training before transitioning to sessions of three to four moderate-intensity reps. Even when you can manage sessions of six to 10 reps at high intensity, you should offset them with continuous lower-intensity sessions, plus strength training to maintain muscle. Penn State University advocates no more than 30 to 40 minutes a week above 90 per cent of your maximum heart rate to prevent injury, weakness, tiredness, illness, disrupted sleep and low mood.

Another risk with HIIT is that it’s perceived as an easy option when it’s not. “You’ve really got to push yourself,” says Cowan. “It’s not

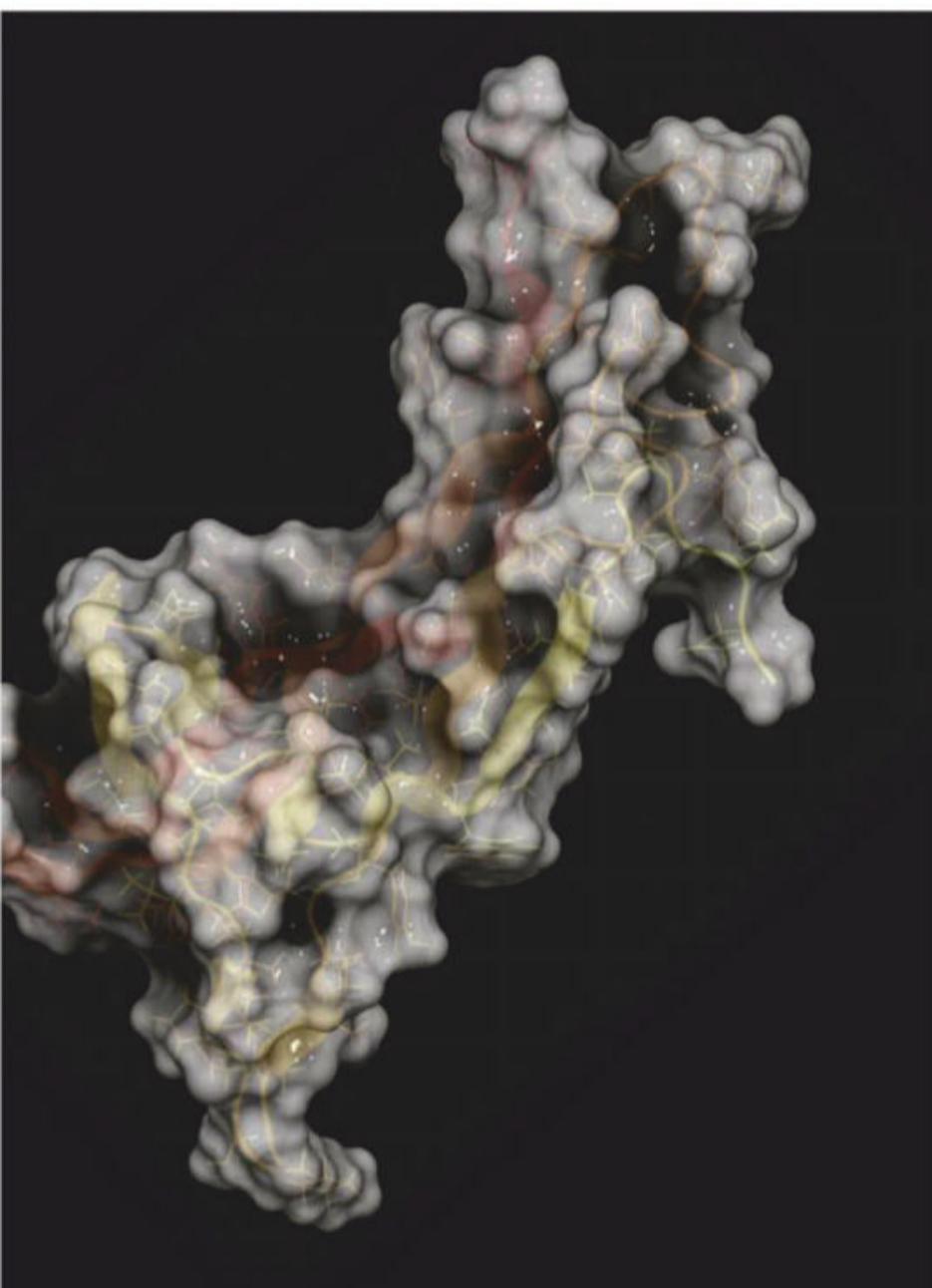


WHAT IF YOU HATE HIIT?

that enjoyable for some people.” That said, HIIT has been rated in some studies as more enjoyable than continuous vigorous and even moderate-intensity exercise. That might be because it’s less mind-numbing, but the University of Turku, Finland, also determined that HIIT releases more painkilling endorphins in the brain. This negates the negative feelings and enhances motivation more than continuous moderate-intensity exercise.

Finally, while short workouts sound enticing, and remove the excuse of lack of time, they may give the impression that only a little exercise is necessary when most people should be getting more, not less. As the ACSM admits: “Meeting the goal of 75 minutes of vigorous activity per week [spread over three days] may prove challenging through HIIT alone.” Alternatively, the ACSM recommends 150 minutes of moderate-intensity exercise per week spread over five days, or a combination of the two. HIIT gets the arduous exercise out of the way quickly, not so you can put your feet up, but so you can enjoy more activities that feel less like hard work. 

Jamie Millar is a freelance fitness writer. He tweets from @mrjamiemillar



GO FOR A WALK

It might sound pedestrian, but just 20 minutes a day cuts your risk of premature death by nearly a third, according to the University of Cambridge. Walking also improves brain function in dementia sufferers and prolongs the lives of cancer patients. If you can't stroll more, then speed up: a study in the *British Medical Journal* linked an average or brisk pace to less likelihood of death from cardiovascular disease.



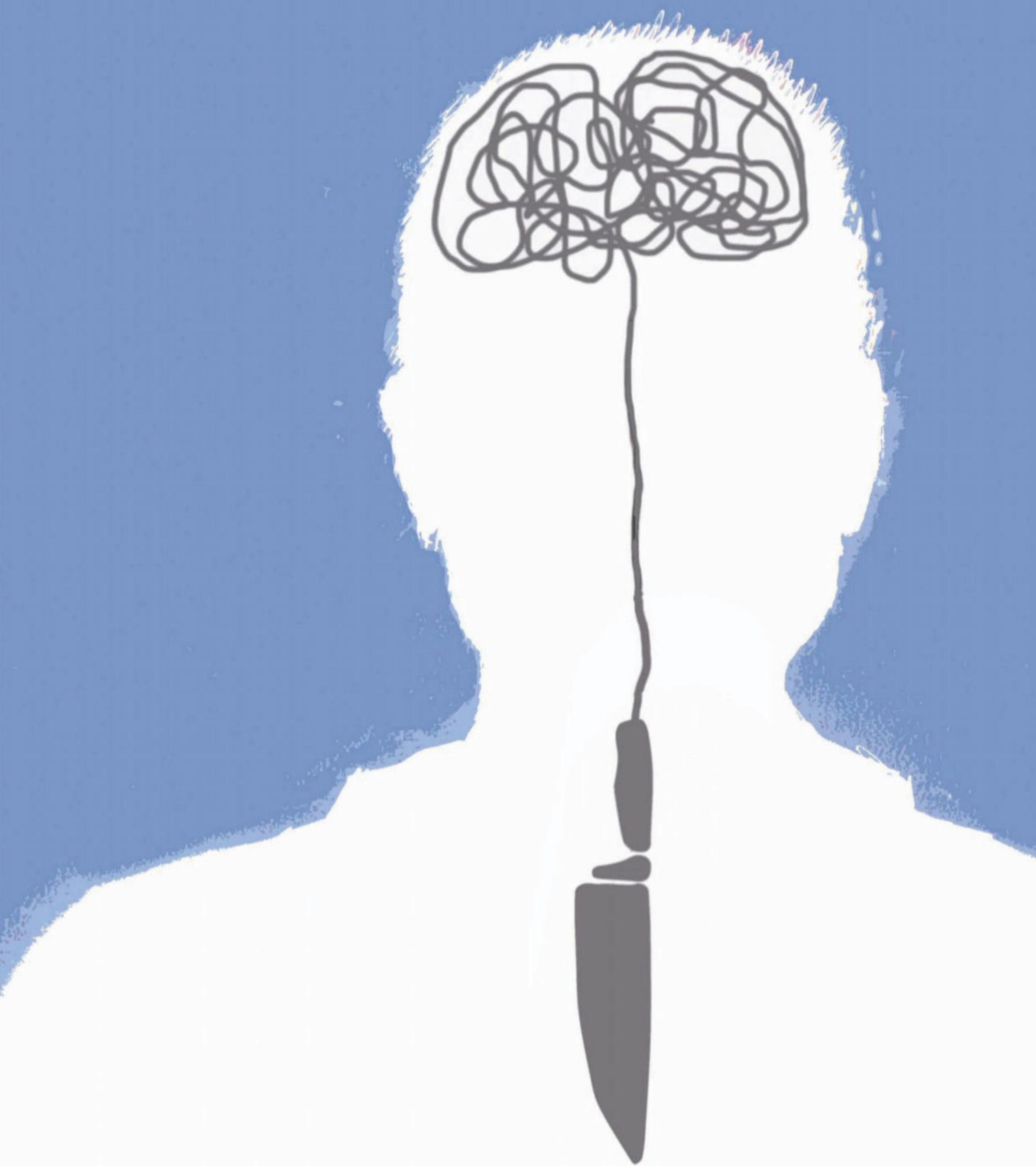
TAKE A SAUNA

Sweating doesn't have to be hard work: the University of Eastern Finland found that half an hour in the sauna lowers blood pressure and raises heart rate, at similar levels to moderate-intensity exercise. The Scandinavian custom is also associated with reduced risk of hypertension, respiratory and coronary disease, sudden cardiac death, Alzheimer's and dementia, plus lower levels of C-reactive protein (a marker of inflammation).



HAVE A BATH

Last year, a study at Loughborough University found that an hour in a hot bath burnt 140 calories. That's fewer calories burnt than cycling for 60 minutes, but the same as a 30-minute walk: not bad for just lying in hot water. The bathers' anti-inflammatory response, which helps fight off infection and illness, was also comparable to exercise. However, their peak blood sugar after eating was actually 10 per cent lower than the cyclists'. Pass the bubble bath.



MY BRAIN MADE ME DO IT

A growing body of research has found that head injury can make people more prone to criminal behaviour...

WORDS: LINDA GEDDES

The tumour growing in the front of the schoolteacher's brain was the size of an egg. It was the likely source of his recent headaches, balance problems, and difficulties writing and drawing. But these symptoms paled in comparison to the personality change that the tumour apparently brought about. Several months earlier, the man had been arrested after making sexual advances towards his prepubescent stepdaughter; he had also amassed a trove of pornography, including indecent images of children.

He knew his urges were unacceptable, yet claimed that his 'pleasure principle' overrode his restraint. He also insisted that this interest in children – and his

compulsion to act upon his sexual urges – was new. It was certainly plausible, his doctors concluded. The tumour was growing in the right lobe of his orbitofrontal cortex, which is a brain area linked to social behaviour, judgment and impulse control. Once the tumour was removed, his deviant urges apparently disappeared, and his drawing, writing and balance improved. He successfully completed a Sexaholics Anonymous programme, and was allowed home. But the following year, he began secretly collecting pornography again, and a brain scan showed the tumour was regrowing. Once more, he underwent surgery to have it removed.

We often assume that paedophiles or people who commit other atrocious ➤

GETTY

• acts are nothing like us; they were either born bad or became that way because of maltreatment during their own childhood. Increasingly though, brain injury – caused by a blow to the head, a stroke, or a tumour pressing on neighbouring brain tissue – is being recognised as another factor that can predispose to or trigger criminal behaviour. Sometimes these injuries bring about personality changes so obvious that they raise immediate alarm bells, but more often the personality change is subtler, and the brain injury goes undetected.

It's not only serious crimes like paedophilia or murder that are being linked to brain injury: a recent study of 613 men who were screened upon admission to Leeds Prison revealed that 47 per cent of them had experienced at least one traumatic brain injury – a serious blow to the head where they'd either lost consciousness or felt very dazed or confused – with most of them being injured before committing their first offence.

“BRAIN INJURY CAN PREDISPOSE TO OR TRIGGER CRIMINALITY”

Not only could the diagnosis of such brain damage result in more effective rehabilitation programmes that reduce reoffending, but by studying the affected brain networks scientists are gaining new insights into the nature of criminality itself.

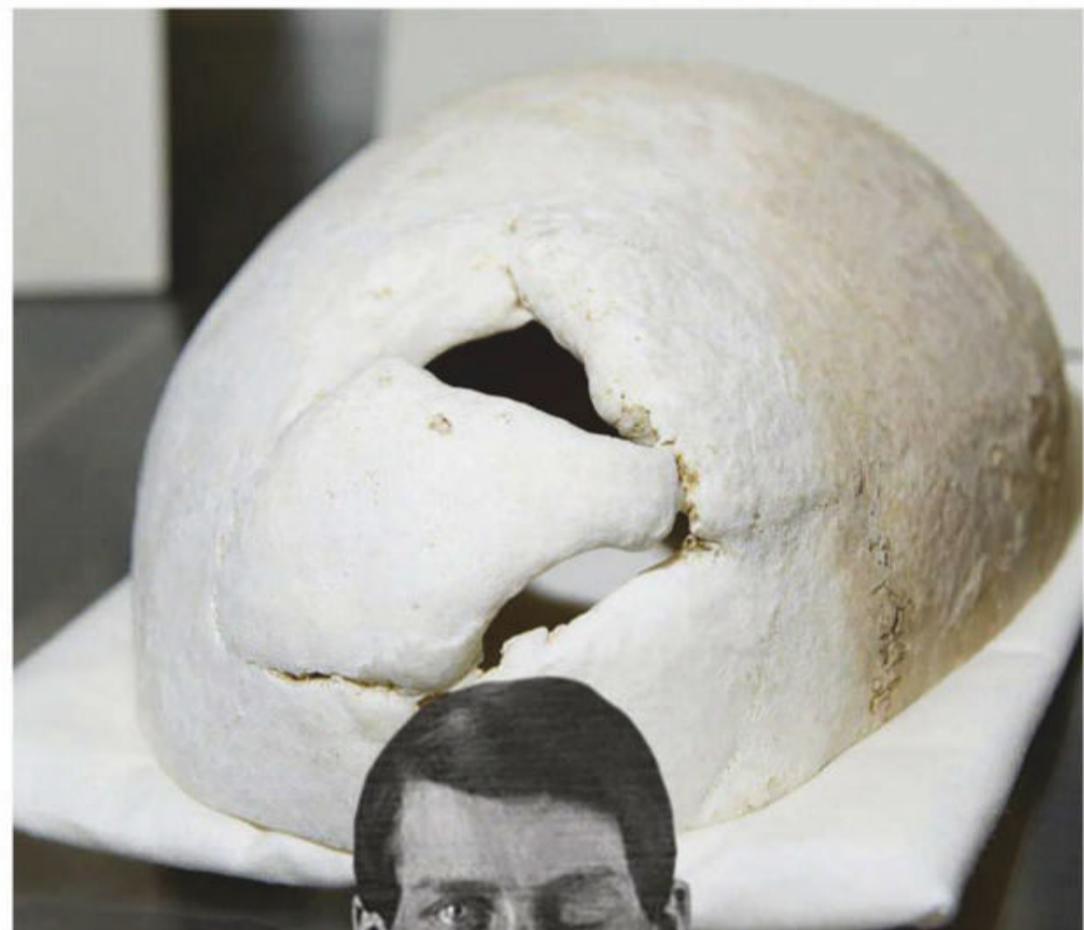
DAMAGED BRAIN

The idea that brain damage could trigger personality change has a long history. One of the first documented cases was that of Phineas Gage, a 25-year-old American railway construction worker who, in 1848, survived an accident which saw an iron rod driven through his left cheek and out of the top of his head, destroying much of his brain's left frontal lobe.

“Gage purportedly changed from being a relatively nice chap to somebody with more antisocial personality traits,” says Dr Michael Craig, a consultant psychiatrist and reader in forensics and neurodevelopmental sciences at King's College London. He became stubborn, foul-mouthed, and quick-tempered; friends said they no longer recognised him as Gage. “From that came the general idea that there are regions of the brain that, if affected by an injury, surgery or a tumour, can actually change someone's personality,” Craig adds.

Since then, scientists have discovered much more about how the brain works and the relative role of

BOTTOM: Phineas Gage survived after an iron rod (held by Gage in this image) was blasted through his brain. His skull (below) is on display in Harvard Medical School. The hole is where the iron rod exited through the top of his skull



its constituent parts. For instance, the frontal lobes – which include the orbitofrontal cortex, where the schoolteacher's tumour was growing – sit just beneath the forehead and are thought to be where many higher functions such as planning, problem solving and decision-making take place. These regions also regulate impulses and social behaviour.

Craig and his colleagues have also studied the brains of people with seemingly more innate antisocial personality traits, such as psychopathy. They recently discovered abnormalities in the uncinate fasciculus – the 'wires' connecting the frontal lobe to the emotion-regulating amygdala – in psychopaths convicted of violent crimes including rape and murder, compared to non-psychopaths. "We found that it was bumpier or less well-formed than it was in people who didn't have psychopathy," Craig says. The worse their antisocial behaviour, the greater the abnormality seemed to be.

Other researchers have reconstructed the injuries sustained by Gage using modern imaging and computer software, discovering that he too must have sustained damage to the uncinate fasciculus, as well as to the prefrontal lobes. The uncinate fasciculus is composed of white matter, which coordinates the flow of information between different brain regions. Some of Craig's colleagues have also identified abnormalities in the grey matter of psychopaths' brains, which is involved in the processing of information. "There is a developing idea that it is not so much one region or another [that governs antisocial behaviour], but networks of regions that are important," Craig explains. In the case of the uncinate fasciculus, it forms part of the limbic system – a network of different brain regions involved in our emotional and behavioural responses to the world around us.

If it's damage to entire brain networks rather than specific regions that matters, this could help explain a puzzling finding: "As a neurologist, one of our dirty little secrets is that often the location of brain damage doesn't link up with where we think the symptoms are coming from," says Dr Michael Fox, an associate professor of neurology at Harvard Medical School in Boston, US. Take Broca's aphasia, a condition in which people struggle to speak fluently, often as the result of a stroke. It is assumed to result from damage to Broca's area, a region in the brain's left anterior frontal lobe, involved in language processing. Yet when you scan the brains of people with Broca's aphasia, the damage is often elsewhere. Importantly, these various brain lesions all connect to the left anterior frontal lobe.

MAPPING THE MIND

In recent years, Fox has linked many such medical symptoms to different brain networks, using a map of the human brain's connections called the Human Connectome. More recently, he and his colleagues turned their attention to criminal behaviour. The ➤

COULD VIRTUAL REALITY HELP CURE BAD URGES?

Inside a small room at a high security hospital in Montreal, Canada, synthetic animations of naked children and adults are projected onto a screen. The men watching them are wired up to devices that track their eye-gaze, the electrical activity of their brains, and the flow of blood to their penises in order to build up a more accurate picture of their sexual preferences than they might be prepared to admit themselves.

Each year, Dr Patrice Renaud and his team assess some 70 to 80 sex offenders this way, to help judges establish the risk they pose to society before deciding their sentences. For instance, not all child molesters are sexually attracted to children – sometimes their offence is prompted by another mental health problem – an important distinction to make in terms of their treatment. "Virtual reality enables you to simulate every possible context that you could imagine, which is a major asset when you're talking about criminal behaviour," Renaud says. "When the avatar is mimicking a child, the individual that we assess has the impression of being seated in front of a real child, which is more potent as a

stimulus than using 2D pictures."

He believes virtual reality could also play a role in the rehabilitation of sex offenders. It could be used to teach offenders about how their brain responds to certain situations, or to help them develop skills they're deficient in, such as empathy. Already, this is being tested in the context of domestic violence. At the University of Barcelona, first-time offenders undergoing a rehabilitation programme are offered a session in which they embody a female avatar who encounters an aggressive male. He criticises their appearance, smashes a phone against the wall and then advances towards them. After the session, the perpetrators' ability to recognise signs of fear in female faces improved.

"An important aspect of treating someone is that they will be able to use the skills you teach them in the real world," explains Renaud, who isn't involved in the Spanish research. "If you learn in virtual reality that you can feel something for an avatar, or that you can't get too close to an environment or a bad thing will happen, then the trainee is more likely to transfer those lessons into real life."



ABOVE: Offenders can be given a virtual reality avatar to help them develop skills and learn more about their brain in a safe environment

SLEEPWALKING SUSPECTS

Can you be guilty for a murder you committed in your sleep? In 2008, when Brian Thomas strangled his wife, Christine, he claimed to have been in the throes of a nightmare about a 'boy racer', who he was fighting off after he broke into the campervan that they were sleeping in. At trial, the judge said Thomas bore no responsibility for his actions, and he was released. He was, however, advised to seek treatment for his 'night terrors'; a disorder in which people experience sudden and intense dread during sleep, and which, in the most severe cases, is associated with injury to themselves or other people. Thomas was also a frequent sleepwalker.

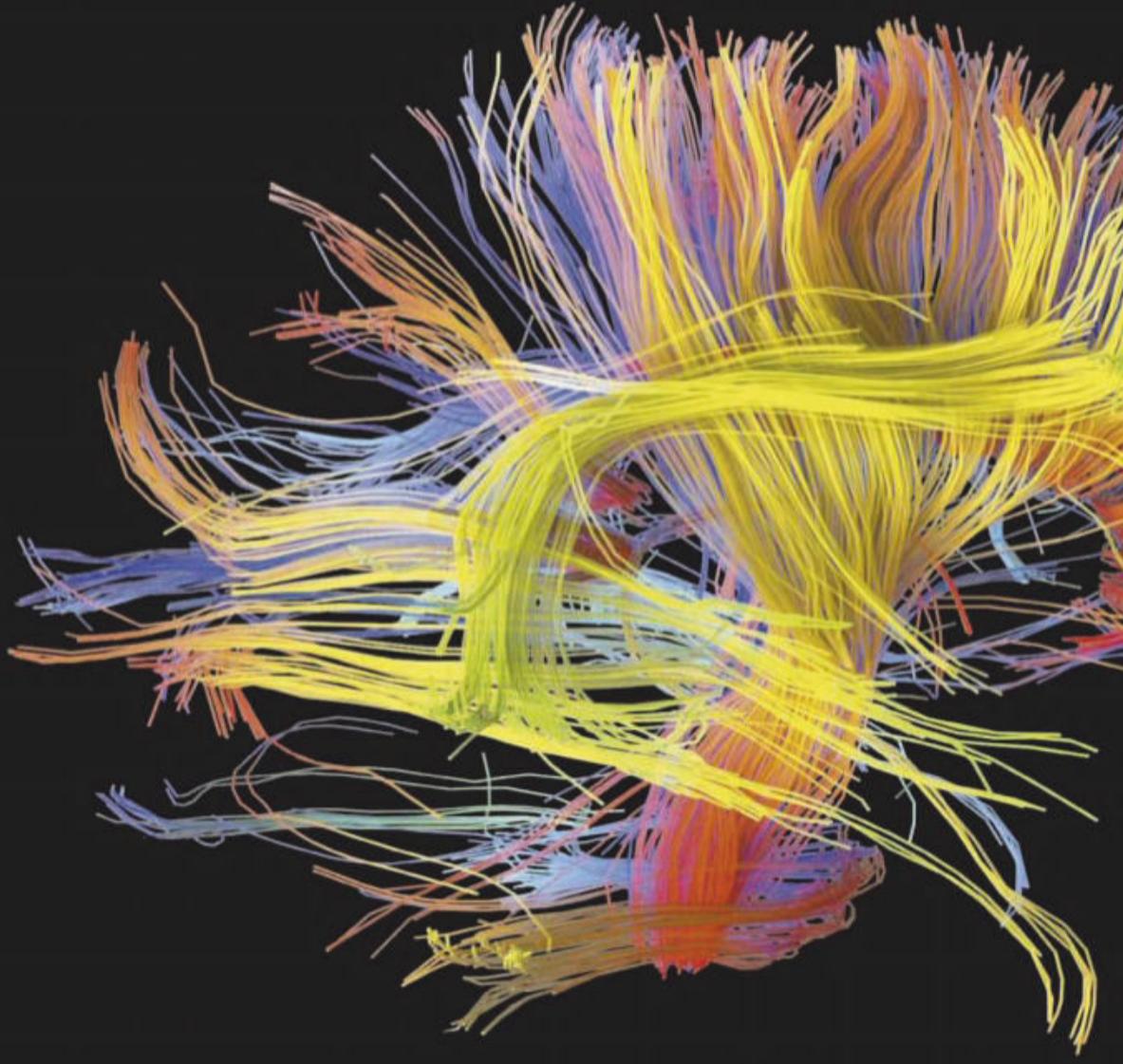
In such cases, perpetrators can use a legal defence called automatism, which means they had no control over their body at the time of the crime. When people are sleepwalking, their prefrontal cortex – the area of the brain responsible for planning, judgment and impulse control – is effectively sleeping, even though other areas are wide awake.

The automatism defence can't be used if someone did something that caused them to lose control over their body, however. For instance, when a British man called Zack Thompson raped a woman while holidaying in Portugal, his claim that he was sleepwalking was undermined by the fact that he had drunk seven or eight pints before falling asleep.



ABOVE: Brian Thomas and his wife Christine prior to the tragedy

BELOW: Brian Thomas leaves court accompanied by his two daughters, after being found not guilty of the murder of his wife

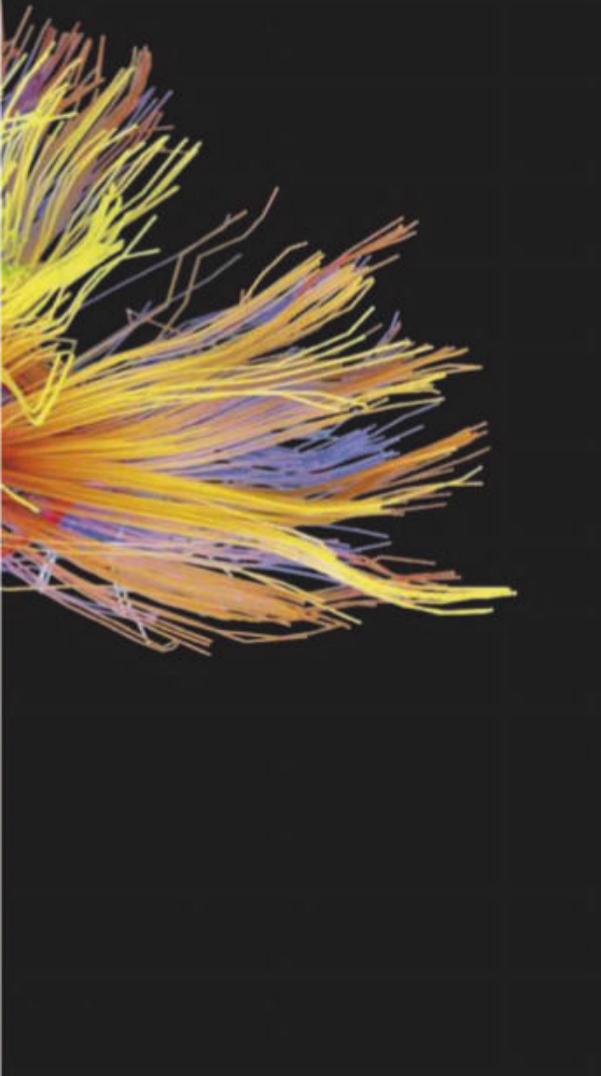


● team searched the medical literature for case reports of patients who had been normal, law-abiding citizens until experiencing a brain injury, such as a stroke, brain bleed or tumour, which apparently prompted them to start committing crimes. They identified 17 case reports where the brain images were good enough that they could be mapped onto the Human Connectome. Although the damage affected different brain regions in the various individuals, their lesions all mapped onto a common network: one which becomes active when healthy people make moral decisions, such as whether it's okay to steal a loaf of bread if your family is starving.

Although the schoolteacher's case wasn't included in their analysis, Fox says he is aware of it: "His lesion location showed exactly the same connectivity profile as all of the other lesions that were included in our network," he says. So too, did the injuries sustained by Gage. But Fox cautions that many more patients need to be examined before they can be sure of the existence of a brain network that can be reliably associated with criminal behaviour. However, if their finding holds true, it could have profound social and legal implications. Already, there have been a handful of British court cases in which a defendant's brain injury or medical condition has been used as a mitigating factor when determining their sentence or their entitlement to compensation. A reliable test would make such decisions easier. "In theory, you could take our network and say 'does the lesion fall within this network or does it not,' and if it doesn't, it would certainly decrease the chances that that lesion was contributing to the criminal behaviour," says Fox.

Around the world, courts are now turning to neuroscientific evidence as growing numbers of defendants' claim that a brain injury or disorder

ABOVE: White matter fibres, as seen in this 3D scan, coordinate the flow of information between different areas of the brain. Flaws in white matter have been linked to psychopathic traits



“VIEWING AN INMATE’S BEHAVIOUR THROUGH THE LENS OF BRAIN INJURY CAN BE HELPFUL”

was the underlying reason for their criminal behaviour. However, it doesn't always work in their favour: in a US case, a man called Richard Hodges arrived at court to plead guilty to burglary and cocaine possession, but appeared lost, confused, and asked irrelevant questions. This prompted the judge to order a brain scan and neuropsychiatric assessment.

The conclusion: Hodges was faking it.

PRISONS AND PRISONERS

Yet research like Fox's could prompt questions about how to handle criminals with more subtle abnormalities in their brain networks – perhaps arising during development, or as a result of childhood neglect. “Do we treat them as criminals who need to be locked up and isolated from society, or do we treat them as patients in need of treatment to improve their symptoms?” asks Fox.

For now, that question remains a largely theoretical one: there isn't yet an effective treatment for adult psychopathy, for instance. But as we learn more about the changes underpinning antisocial behaviour, the chances of us finding one grow stronger. Similar questions often cross Dr Ivan Pitman's mind. As a clinical psychologist who has spent his career working with offenders – some of them detained in Ashworth Hospital in Merseyside – his research suggests that undiagnosed brain injury may be a contributing factor in more criminal cases than is widely recognised. It may also be impeding rehabilitation efforts.

Ashworth houses some of the UK's most violent prisoners; men whose criminality is judged to stem from mental illness – a chemical imbalance in the brain, which could potentially be corrected with drugs. Pitman wonders if in some cases, it might arise from a physical brain injury, which is less reversible. “Once brain tissue is dead, it's dead. The brain copes by finding new pathways for signals to go around, but it is never as effective as it was before,” he says.

He and his colleagues began reassessing some of Ashworth's most difficult inmates using a combination of cognitive tests and brain scans: this revealed that

many of them had previously undiagnosed injuries to their brains. This doesn't necessarily excuse their bad behaviour; after all, there are plenty of people with brain injuries who don't commit crimes. “Brain injury does not inject criminality or antisocial behaviour, but what it can do is remove some of the inhibitors,” explains Pitman.

Even so, viewing an inmate's behaviour through the lens of brain injury can be helpful. “It means that we can start to look at things much more functionally: not that this person is bad, or is trying to upset or annoy you, but actually, perhaps this person doesn't quite understand what is expected of them, and doesn't quite understand the things that you understand,” says Pitman.

It also has implications for their treatment. People with brain injuries can often come across as quite normal during conversation, but they may struggle to fully comprehend what people are saying to them. They may also find it difficult to multitask, set goals or make decisions – a phenomenon called the frontal-lobe paradox.

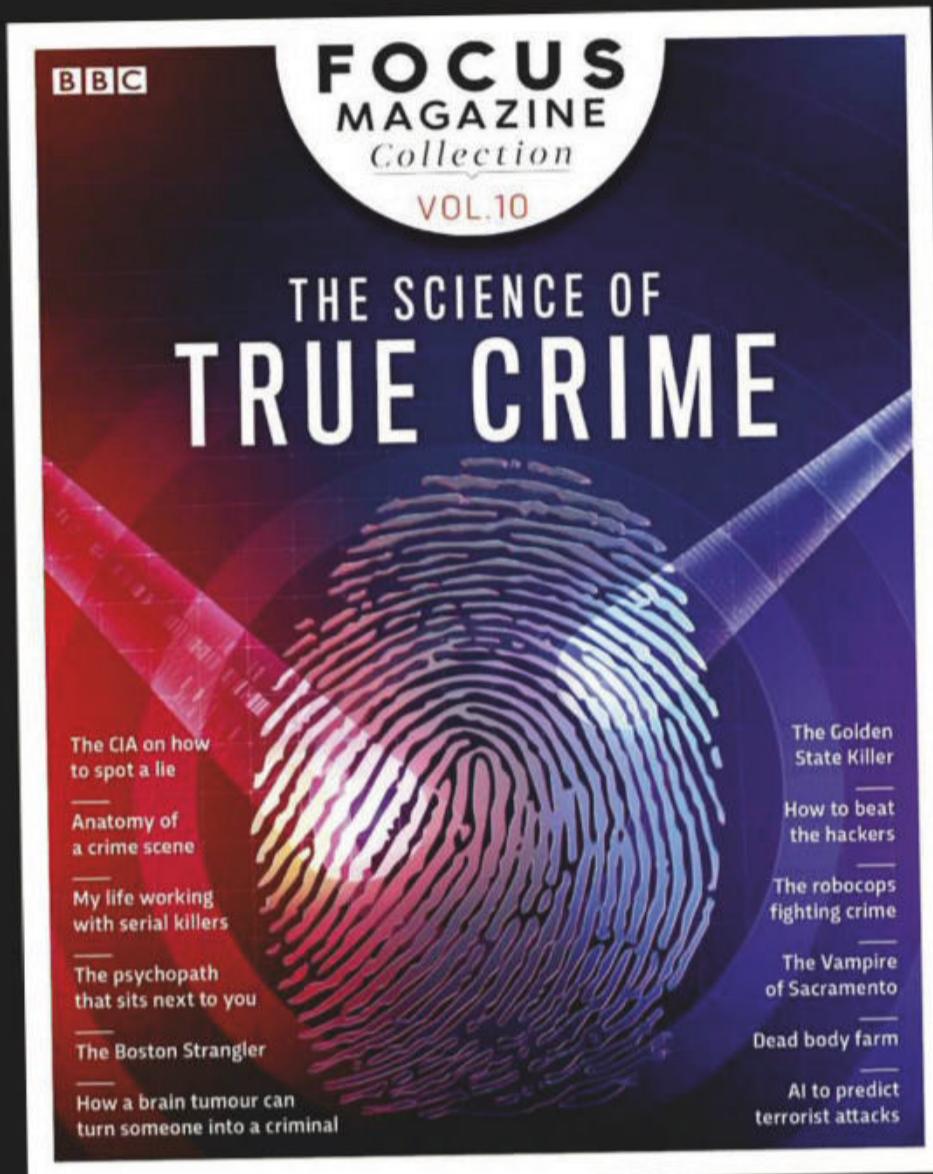
When someone who hasn't committed a crime sustains a brain injury, they will be assessed by a team of psychologists, occupational therapists and physiotherapists to identify such deficits and develop strategies to help them function in everyday life. Such assessments aren't usually done when someone is sent to a secure hospital or prison, but their treatment and rehabilitation often hinges on psychological interventions – such as relaxation techniques and talking therapies – which require engagement if they're to be effective. “We have to acknowledge that this way of treating them may not work very well because they're not able to learn and respond in the way that healthy people are,” says Pitman. “Our job is to identify the obstacles they face and find ways of overcoming them.”

Pitman's current focus is on the general prison population. As his study of inmates at Leeds Prison revealed, up to half of prisoners may have experienced a brain injury in their past. And although many of these injuries are mild, an estimated 15 per cent are moderate or severe, which means those affected may be struggling with everyday tasks.

Brain injuries can't be fixed, but given the right environment, people can learn to work around them to some degree. As Pitman says, “By failing these people, there's a risk of further victims being created.”

Linda Geddes is a freelance science journalist, who writes about biology, medicine and technology. She tweets from [@LindaGeddes](https://twitter.com/LindaGeddes)

THE SCIENCE OF TRUE CRIME



This *BBC Focus Special Edition* reveals the cutting-edge techniques being used to catch criminals...

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- How **psychological profiling** changed the FBI
- The **DNA detectives** solving unsolved crimes
- How **brain injuries** can create criminals
- Take a test to see if **you are a psychopath**
- How maths can help predict **terrorist attacks**
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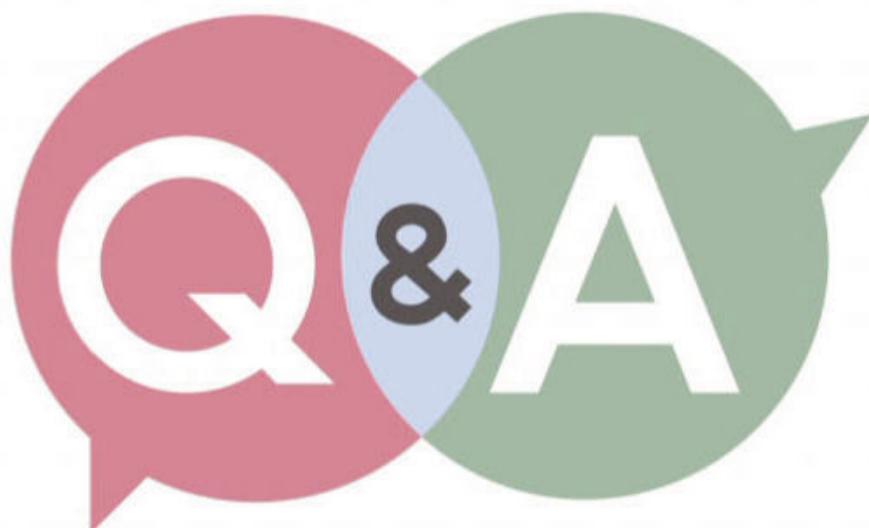
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Science/tech
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DR GILES YEO
Geneticist,
food expert



PROF ROBERT MATTHEWS
Physicist,
science writer

YOUR QUESTIONS ANSWERED

JANUARY 2019

EDITED BY JAMES LLOYD

Why do my fingernails grow faster in a hot country?

SIMON MAKIN, SCOTLAND

In 1941, American doctor William Bennett Bean began a 35-year study of his own fingernail growth, concluding that climate, season and geographical location have no effect on growth rate. However, other studies have found a slight increase in growth during the summer – probably due to increased blood supply to the fingertips. But if you notice a sudden change while on holiday, it's more likely that your nails just aren't being worn away so fast while you're relaxing by the pool, and the actual growth rate hasn't increased very much. **LV**

Shridhar Chillal stopped cutting the nails on his left hand in 1952 and finally had them cut short in July 2018. The record-breaking nails had a combined length of more than nine metres





Why do elephants have such wrinkly skin?

LYDIA COLEBROOK, LEEDS

The African elephant's wrinkly skin was recently put under the microscope by researchers in Switzerland. They found that the wrinkles are actually a complex web of 'microvalleys' formed as the outermost skin layer ('epidermis') thickens and bends with age, causing it to crack. This fissured skin surface retains five to 10 times more water than a smooth surface, which helps to keep the elephant cool as the moisture (from rain or mud) evaporates from the cracks. Unsurprisingly, Asian elephants have smoother skin than their African cousins, as they live in wetter environments and have less trouble keeping cool. **CC**

Why do young children pick their noses and eat it?

BECCA IRVEN, HASLEMERE

*Everyone – adults and children alike – occasionally picks their nose to free up the passages. In fact, the diameter of our nostrils has probably evolved to match our finger size, for this reason. Children often eat their bogies because they are curious, and it's a convenient method of disposal. There's no particular medical or dietary advantage, but eating bogies is harmless. **LV***



Can I raise my dog or cat as a vegan?

JOSIE LOTT, LONDON

It's theoretically possible for dogs, but difficult in practice. Dogs have co-existed with humans for at least 14,000 years and have evolved some extra digestive enzymes that help them to digest plant starches, probably as a result of sharing our food. But a 2015 study at the University of California, Davis, found that 25 per cent of commercial vegetarian dog foods lacked the right balance of essential amino acids. And homemade diets are even worse: a 1998 study found that 50 per cent of dogs fed homemade vegetarian or vegan food had dietary deficiencies.



For cats, it is even harder to balance. Cats are entirely carnivorous in the wild, and there are several amino acids only found in meat, such as taurine, that they can't synthesise or store, so a vegan cat diet has to be very carefully tailored to their age and body weight. Too little taurine can cause blindness and heart failure, while too much can lead to serious urinary tract infections. Carnivorous cats absorb all the taurine they need from meat, but synthetic taurine added to vegan food comes in several different forms, which are absorbed by the cat's metabolism at different rates. This makes it extremely difficult to give cats a balanced vegan diet. **LV**



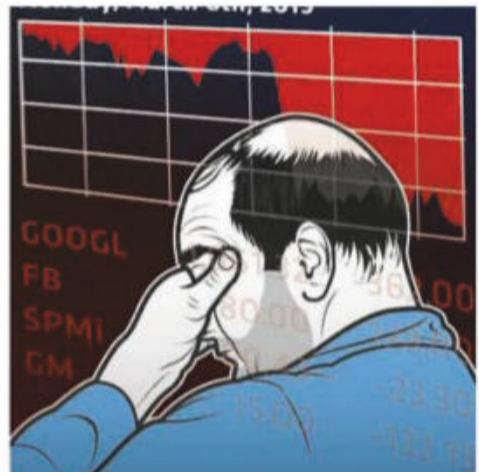
Why does time seem to go faster as we get older?

TED LEECH, MANCHESTER

It may simply be a matter of perspective. After all, one year to a five-year-old is a significant portion of their lifetime to date, yet to a 60-year-old it is just a tiny fraction. Other experts say it has more to do with how, the older we get, the more familiar life becomes, and the more we 'chunk' our experiences into basic categories like 'work', 'commuting', 'shopping' and 'home life'. One study found that prompting people to categorise the previous year in this way led them to feel that it had passed more quickly. The good news is that this also points to an antidote – being mindful and savouring each experience as if it were new ought to trigger the sensation of time passing more slowly. **TL**

THE THOUGHT EXPERIMENT

WHAT WOULD HAPPEN IF... THE INTERNET SUDDENLY STOPPED WORKING?



1. AFTER ONE DAY

At the end of the first day, Facebook and Google have lost over £300m in advertising revenue between them. Most other businesses have ground to a halt as well, since banking, telephone and mobile phone networks all rely on the internet to function.



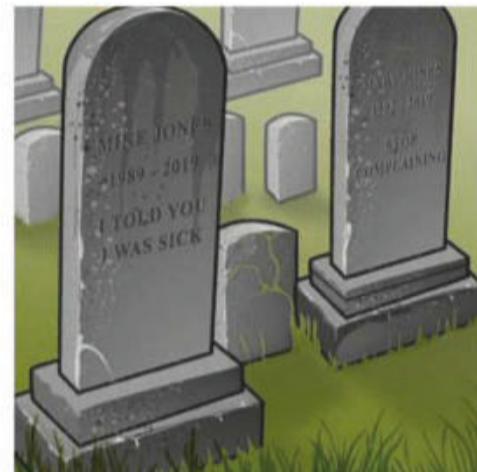
2. AFTER A WEEK

The modern power grid relies on the internet to coordinate power plants and electricity substations. Without it, each country's national grid has become unbalanced, and local outages escalate into a blackout for most of the world. Gas pipelines have shut down since they rely on power and the internet.



3. AFTER A MONTH

Petrol stations use electricity to pump fuel, and they need an internet connection to monitor tank levels, process transactions, and order new deliveries. Without fuel, supermarkets can't deliver food, and riots rage around all the major distribution depots. The army is called in, but they need fuel and supplies too.



4. AFTER A YEAR

In the developed world, most countries have recreated a basic landline telephone network, and have begun to rebuild society. Everywhere else has reverted to an agrarian subsistence economy. The death toll from starvation, cold and unrest is estimated at a billion worldwide. The global economy is back to 1930s levels.

Can artificial sweeteners cause weight gain?

CIARAN SCANLON, KILDARE, IRELAND

The evidence on this is conflicting. Long-term studies with large sample sizes have found a correlation between artificial sweeteners and weight gain, but these tend to rely on diet questionnaires, which aren't accurate. They also can't say whether, for example, diet soda makes you fat, or overweight people are more likely to drink diet soda. A 2016 report by health charity Cochrane evaluated the results of lots of more rigorous short-term trials, and concluded that artificial sweeteners actually *help* with weight loss by replacing sugar calories with non-calorie alternatives. **LV**

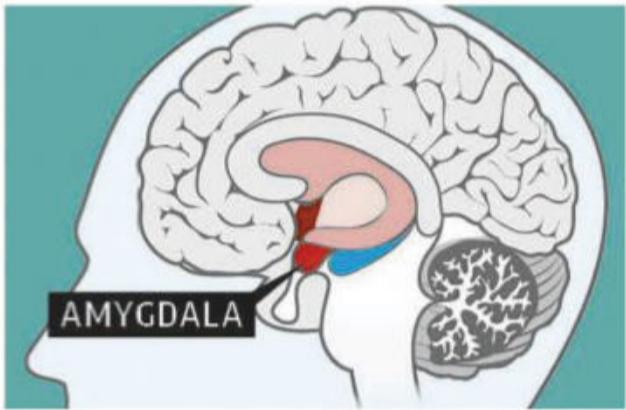


WHAT HAPPENS IN MY BODY WHEN...

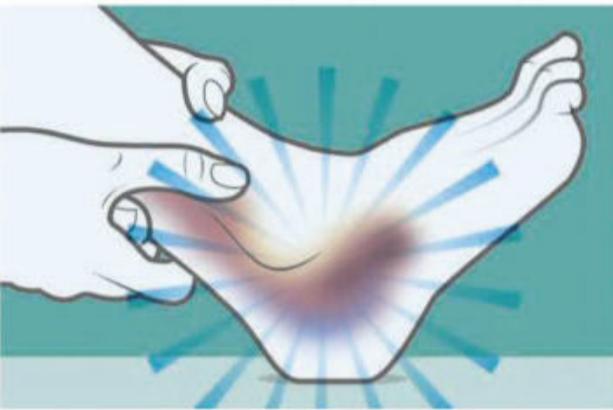
...I meditate?

KELLY MOORE, CHESTER

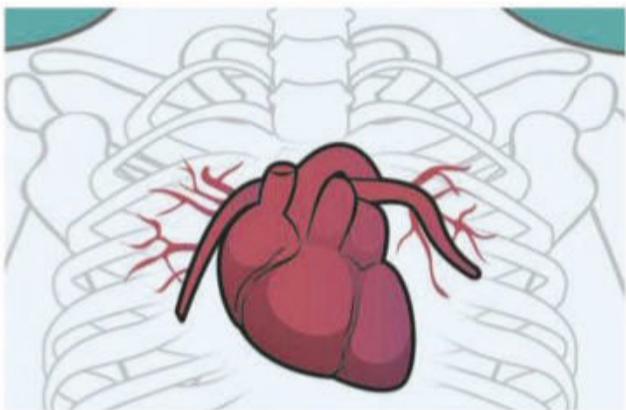
Mindfulness meditation is different from just relaxation. It involves retraining the mind to focus on all the stimuli received by the body, as they arrive. It limits your attention to the immediate present and the signals and reactions of your body. This state of awareness has been shown in numerous studies to cause measurable changes in the brain and the rest of the body that can persist beyond the meditation session.

**1. Brain**

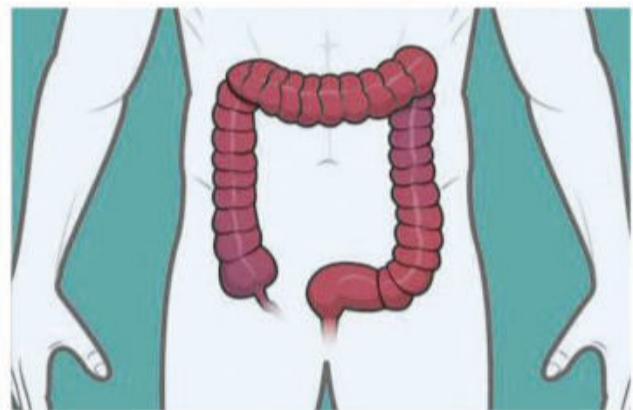
The amygdala – a region of the brain that's important for processing emotions such as fear and aggression – is less active after a meditation session, which helps reduce stress and anxiety levels.

**2. Sprains and strains**

Meditation affects the gene-regulating machinery in our cells and reduces the activity of genes that cause inflammation. This can speed up recovery from physical injury and sprains.

**3. Heart**

Studies have found that meditation lowers blood pressure in people at risk of developing high blood pressure, probably by reducing feelings of anger and anxiety.

**4. Large intestine**

Some studies have suggested small improvements to irritable bowel syndrome (IBS) and ulcerative colitis, possibly by reducing the production of stress hormones. Results are conflicting, though.

**5. Cravings**

A form of mindfulness called 'integrative body-mind training' can help smokers to quit and avoid relapsing afterwards, by altering the activity in the areas of the brain associated with cravings.

**6. Lower back**

Mindfulness has been shown to help control lower back pain, by redirecting your attention from the pain so you automatically relax your muscles. The method can be used in tandem with painkillers.

If bats are blind, why do they have eyes?

LESLIE FINCH, LLANDYSUL

Despite the famous idiom, bats aren't blind. All bats rely on sight to find food, avoid predators and navigate to and from roosts. As expected in a nocturnal mammal, their eyes are heavily loaded with photoreceptor cells called rods, which maximise their ability to see in the dark. At night, however, most bats use echolocation to find prey – sending out ultrasonic sound waves and listening for the echoes. So bats can 'see' with both their eyes and their ears. **cc**



GETTY X2, NASA. ILLUSTRATION: PETER SUCHESKI

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The grey-headed flying fox is one species of bat that does not echolocate. It relies on sight and smell to find its food

How do trees grow straight up, even on a slope?

TE CHASE, VIA EMAIL

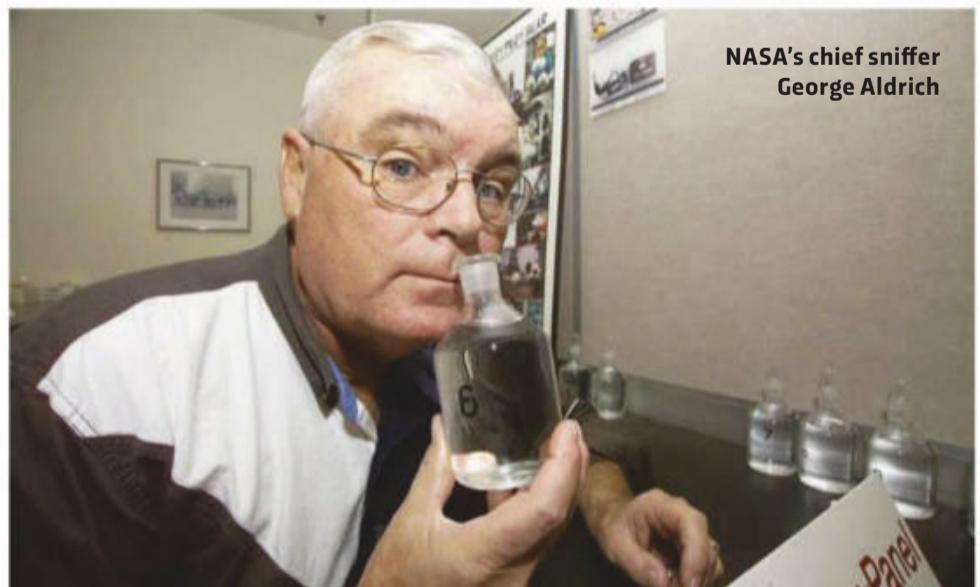
Trees (and most other plants) detect gravity using tiny structures within the cells of their roots and shoots called 'statoliths', which tell them which way is up (a process known as 'gravitropism'). These pocket-shaped structures are also responsible for storing the plant's food (in the form of starch). Statoliths are drawn by gravity towards the bottom of their cell, telling the tree that this direction is down. The tree responds by growing its roots downwards and shoots upwards. If, however, the tree were blown onto its side, the statoliths would shift and settle against whichever part of the cell was now facing downwards. The tree would then use this information to re-orient itself and continue to grow its shoots vertically. **AFC**



Is it true that NASA smells everything before it is sent into space?

GEMMA KING, PLYMOUTH

In 1967, a fire killed three American astronauts during a launch rehearsal of the first Apollo mission. The resulting inquiry led to extra testing of materials used throughout the space programme – and this included sniff-testing. Non-toxic materials can still give off odours that make astronauts feel queasy, especially in the cramped confines of a space vehicle. That in turn can undermine the performance of the astronaut, putting the entire mission at risk. NASA's current 'chief sniffer' is George Aldrich. Sometimes known as 'Nostrildamus', he is tasked with smelling all objects that will be within the habitable areas of the International Space Station. **RM**

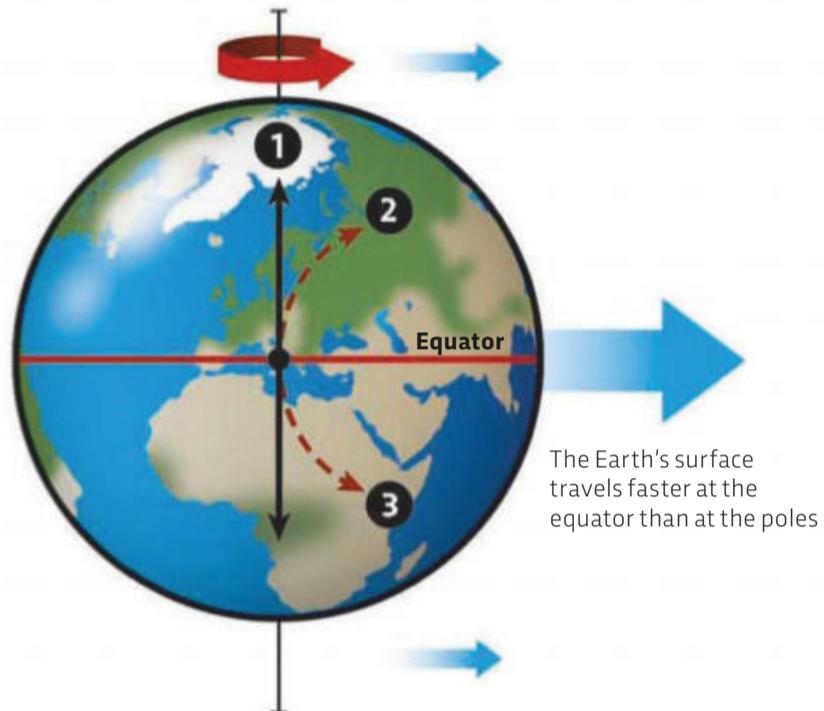


Why do low-pressure systems turn anticlockwise?

ROGER EVANS, ARGYLL

As the Earth spins, the speed of rotation experienced at the equator is much faster than at the North Pole. This difference causes the 'Coriolis effect' – a force which appears to deflect winds towards the right in the northern hemisphere. In a low pressure weather system, air flows inward, but this deflection twists the air flow towards the right, creating an anticlockwise swirl of winds. In a high pressure system, air flows outward, and the deflection results in a clockwise rotation. The Coriolis effect deflects winds towards the *left* in the southern hemisphere, so weather systems here spin in the opposite direction **AFC**

THE CORIOLIS EFFECT



1 Intended path

Imagine a current of air moving from the equator.

2 Actual path (northern hemisphere)

Even though it's moving in a straight line, it appears to an observer to bend towards the right. This is because as it moves northwards, the ground beneath is moving progressively slower and hasn't 'caught up' with the air current.

3 Actual path (southern hemisphere)

In the southern hemisphere, this effect causes currents to bend towards the left.

WHO REALLY INVENTED?

THE MOVIE CAMERA?



THOMAS EDISON



LOUIS LE PRINCE

The invention of the movie camera is, ironically, a story worthy of Hollywood. In 1888, the renowned American inventor Thomas Edison drew up plans to build a camera which could record moving images onto a cylinder. Within a few years, colleagues had produced a more sophisticated device that captured images onto a reel of 35mm photographic film – which remains the standard format. But even as Edison started work, a French artist seemed to have beaten him to the punch. Louis Le Prince had already built a single-lens camera, and in 1888 used it to make a brief silent movie of people walking in a garden. As the oldest movie in existence, *Roundhay Garden Scene* appears to be proof that Le Prince should be credited with inventing the first movie camera. Yet his claim to priority remains controversial because just before patenting his device and taking it on tour in America, in September 1890, Le Prince vanished. His wife suspected foul play, and in 2008 a magazine claimed that evidence had emerged showing Edison had arranged Le Prince's assassination. Yet while Edison certainly had a motive, the 'evidence' has never been substantiated, and the mystery of Le Prince's disappearance remains unsolved. **RM**



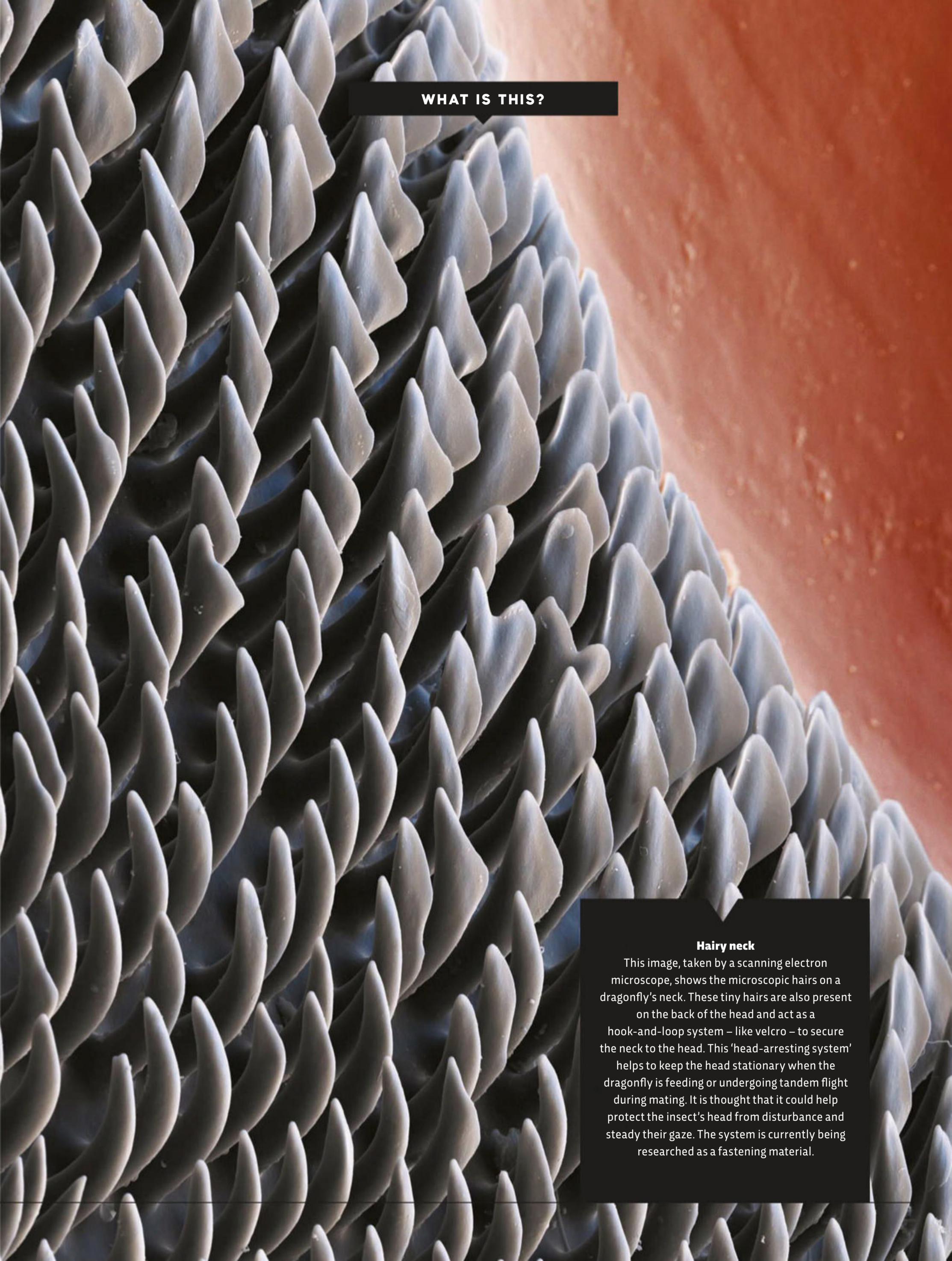
Frames from the *Roundhay Garden Scene*, filmed by Louis Le Prince in October 1888

How tall is the Universe?

STEVE GRANTHAM, PRESTON

Although astronomers often discuss the expansion of the Universe in terms of a two-dimensional plane, the Universe is, of course, three-dimensional (at least in our spatial experience of it). The expansion of the Universe is the same in all directions, so it is just as 'tall' (or 'deep') as it is 'wide'. Unfortunately,

though, we cannot know the size of the Universe. This is because light takes time to reach us from the furthest depths of space: we're currently unable to see beyond around 46 billion light-years (the boundary of the 'observable Universe'). We have no idea how much of the Universe lies beyond that. **AGu**



WHAT IS THIS?

Hairy neck

This image, taken by a scanning electron microscope, shows the microscopic hairs on a dragonfly's neck. These tiny hairs are also present on the back of the head and act as a hook-and-loop system – like velcro – to secure the neck to the head. This 'head-arresting system' helps to keep the head stationary when the dragonfly is feeding or undergoing tandem flight during mating. It is thought that it could help protect the insect's head from disturbance and steady their gaze. The system is currently being researched as a fastening material.

WHAT'S IN A SMELL?

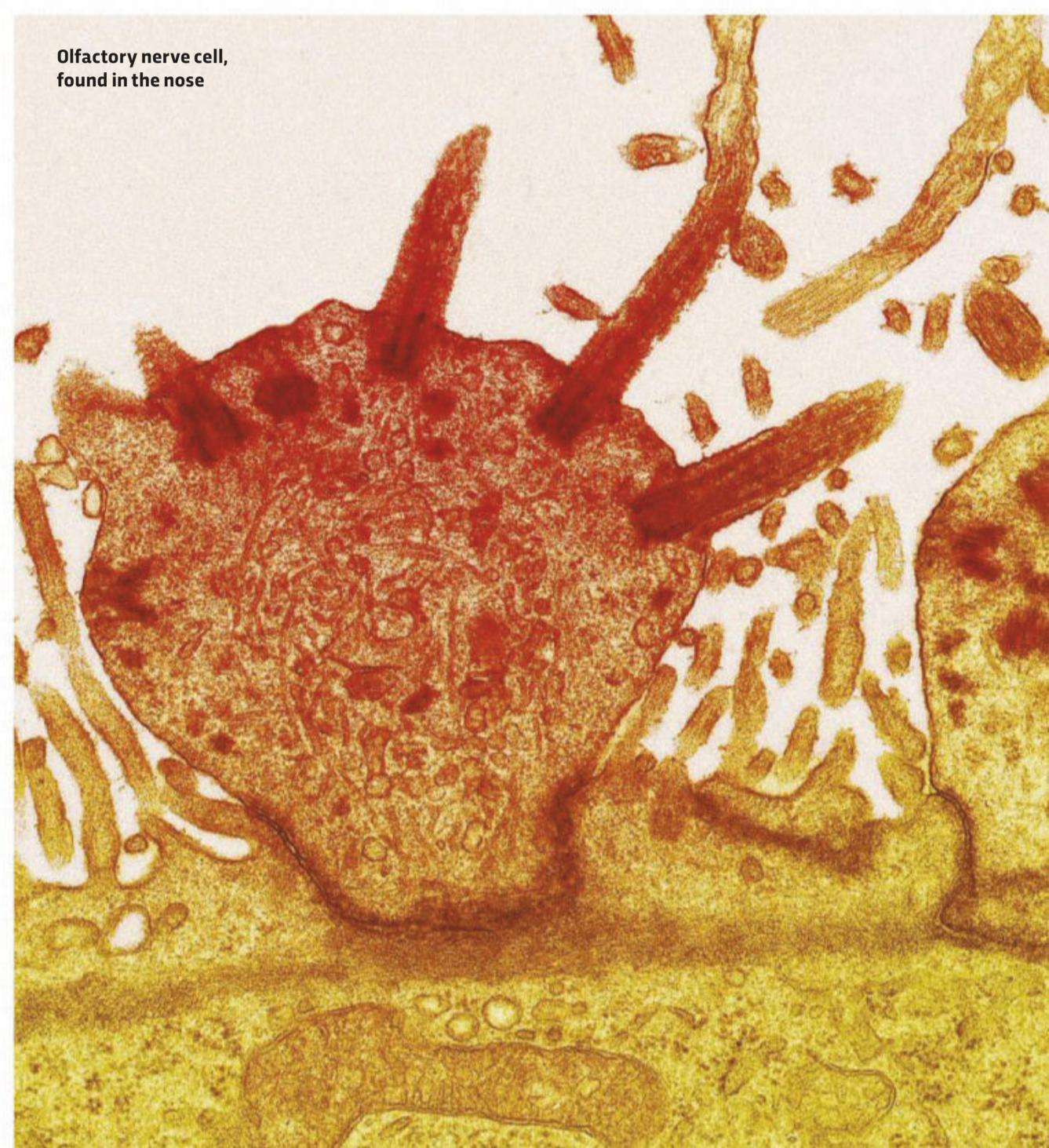
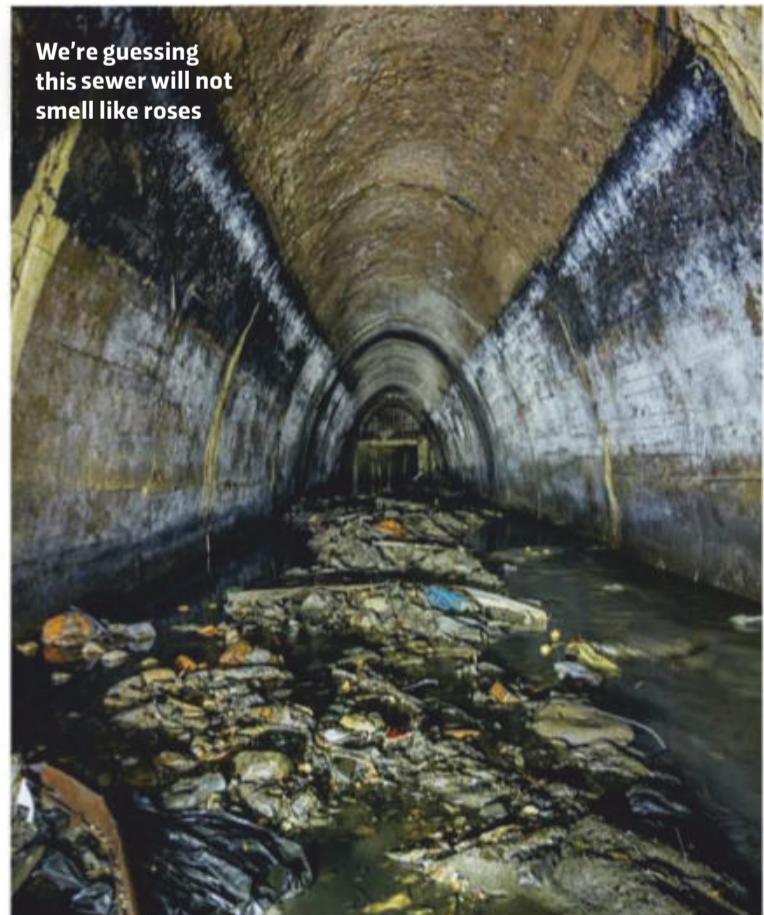
We teamed up with the folks behind BBC World Service's *CrowdScience* to answer your questions on one topic. You can tune into *CrowdScience* every Friday evening on BBC World Service, or catch up online at www.bbcworldservice.com/crowdscience

How does smell work?

If you've ever stopped to smell the roses, a cocktail of hundreds of different odour molecules will have wafted through the air and up your nostrils. At the top of your nose, the molecules bind to special smell receptors on the surface of nerve cells, which send a signal to the brain's olfactory bulb, located just behind the bridge of the nose. Humans have around 400 different smell receptor types, and one odour molecule may bind to many of them. Together, the odour molecules create a pattern of activation in the nerve cells that our brain interprets as 'a smell'.

Why do we like certain smells but not others?

Smells can warn us about danger – we're repelled by the smell of sewage and rotting food, for example. But according to smell expert Dr Andreas Keller from Rockefeller University, it's difficult to tell whether we're born with these preferences or whether they're learned. Context plays a big role. Butyric acid is a chemical that contributes to the smell of both Parmesan cheese and vomit, so it may smell repulsive or appetising, depending on the situation. The answer is also partly down to our DNA – the genes that code for our smell receptors can vary between people, so we don't all respond to odour molecules in the same way.



What happens when we lose our sense of smell?

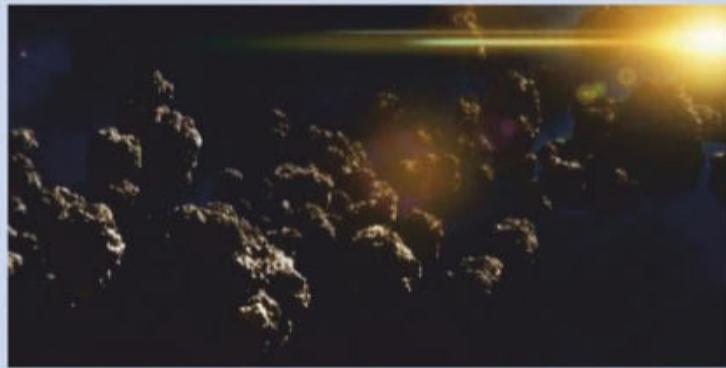
We all have at least one genetic 'blind spot' in our sense of smell, which means we simply can't detect certain odour molecules. One famous example is how only some people notice a strong odour in their pee after eating asparagus. Anosmia – a complete loss of smell – can occur after a cold, sinus infection or even a bump to the head. Anosmia impacts the flavour of food, but goes far beyond that – one anosmiac has described it as like "living behind a pane of glass". Luckily, anosmia isn't always permanent, and may recover naturally or through exercises like 'smell training', which uses distinctive smells such as essential oils to re-stimulate the olfactory system.



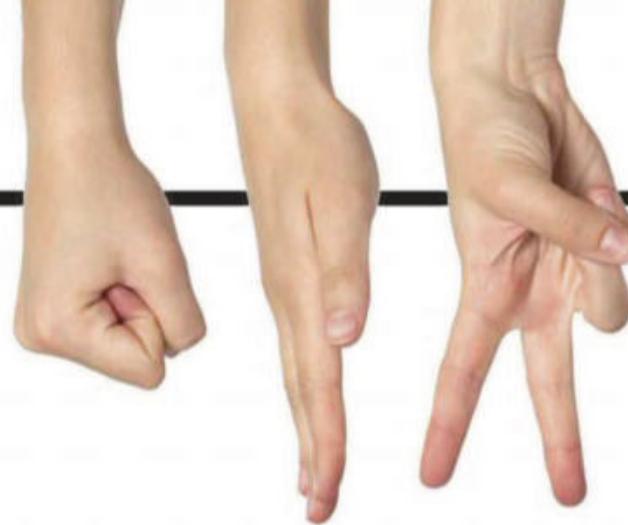
Anand Jagatia is the presenter of *Do You Smell What I Smell?* – an episode of *CrowdScience* that can be streamed at www.bbc.co.uk/programmes/w3csvvxk

If all the asteroids in the asteroid belt had coalesced to form a planet, what size would it have been?

ADAM KING, HUDDERSFIELD



Surprisingly, the total mass of material in the asteroid belt is only about 4 per cent of the mass of the Moon. About half of this mass is contained in the four largest asteroids: Ceres, Vesta, Pallas and Hygiea. If all this material were concentrated into a single object with the same density as Ceres, it would be a dwarf planet about 700km in radius (Pluto, another dwarf planet, has a radius of 1,188km). Such a small object would have little impact on the Solar System as a whole. **AGu**



IN NUMBERS

50

The percentage of the world's annual rainfall that falls on the 12 wettest days of the year.

9 in 10

The number of adults in England who have at least one unhealthy trait: smoking; drinking more than 14 units of alcohol a week; eating fewer than five portions of fruit and veg a day; being obese; or having low levels of physical activity. This is according to data from Health Survey for England.

QUESTION OF THE MONTH

How does the phone network know where to send the signal when someone rings me?

AMY ROUSE, VIA EMAIL

While smartphones are pretty smart, their ability to make and receive calls is due primarily to the clever network they're in touch with. Known as the cellular network, it's made up of thousands of masts across the nation, each able to pick up transmissions from phones in its vicinity. By detecting whose phones are currently nearby (using each phone's unique, 15-digit 'IMSI' code), they can send calls from other parts of the network. As we move, we enter the coverage area ('cell') of a different mast, which notes our presence in turn. The cellular network also means that phones don't have to be powerful: they only have to communicate with the mast in their local cell. The network does the hard work of transmitting the calls across the country and beyond. **RM**



WINNER!

Amy wins a bundle of science books (£50, iconbooks.com). *The Graphene Revolution* introduces us to the wonderful world of graphene; *The Enlightened Mr Parkinson* tells the story of the surgeon who defined Parkinson's disease; myths of gender are explored in *Testosterone Rex*; and we go on a cosmic journey through space and time in *Astroquizzical*.



NEXT ISSUE:

Which came first: plants or seeds?

What happens to toilet paper?

What makes someone beautiful?

Email your questions to questions@sciencefocus.com

OUT THERE

WHAT WE CAN'T WAIT TO DO THIS MONTH

JANUARY 2019

EDITED BY HELEN GLENNY





01

**RSPB BIG GARDEN
BIRDWATCH**
26-28 JANUARY 2019
RSPB.ORG.UK/BIRDWATCH

SPOT BIRDS

Put your winter boots on and make a cup of hot coffee; it's time for the 40th RSPB Big Garden Birdwatch. Over the past four decades, enthusiasts have popped outside for an hour in mid-winter to document the birds that land in their gardens. (If you can't face the cold, you can stay inside and watch from a window!) Since 1979, 130 million birds have been counted in what's become the largest garden wildlife survey in the world.

Plus, the Big Garden Birdwatch provides invaluable information to the scientists at the RSPB. It alerted them to the increasing numbers of collared doves and wood pigeons, but declining populations of song thrushes and starlings. Among other things, the RSPB uses that data to encourage the public to plant shrubs or build particular features in their gardens to create more hospitable habitats for the birds that aren't doing so well. Turn the page to find out more... ➤

RAY KENNEDY/RSPB-IMAGES.COM

WHAT TO LOOK OUT FOR...



GOLDCREST

These are one of the UK's smallest birds, weighing just five to six grams – about the same as a 20p coin. They are native to the UK, but large numbers also migrate here from Scandinavia in the winter. They arrive at the same time as migratory woodcocks, so they were once thought to ride on the backs of the larger birds, earning them the nickname 'woodcock pilots'. Lots of goldcrests nest in the UK, with over 600,000 pairs breeding here annually.



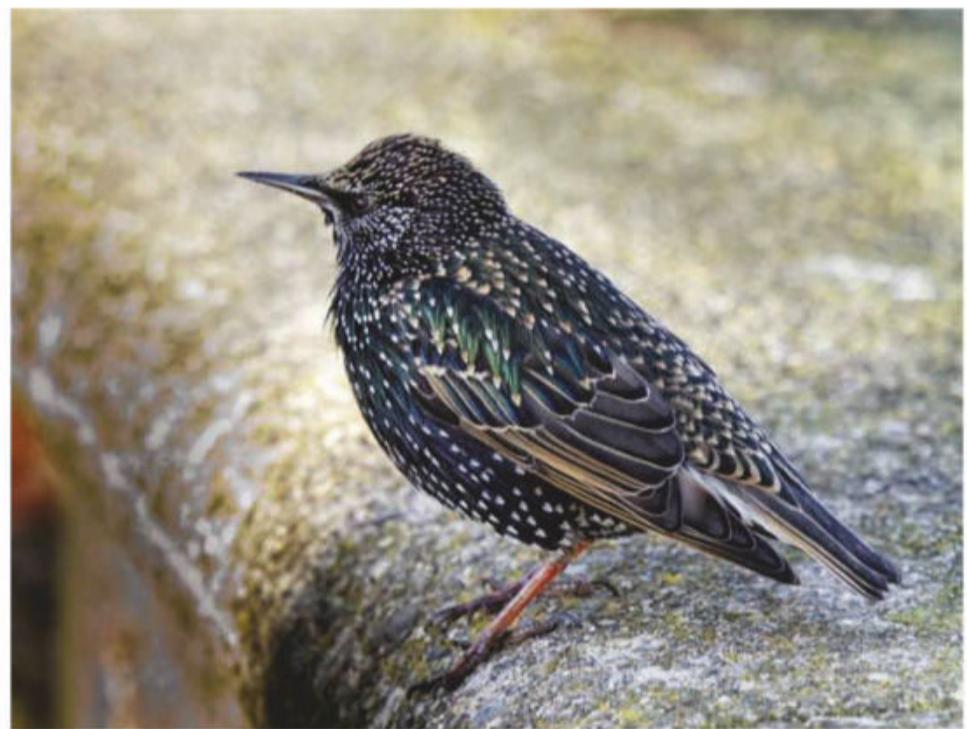
WAXWING

Large numbers of waxwings flock to the east coast of the UK in 'waxwing winters', when there aren't enough berries to feed them in their native forests of northeast Europe. They have an endearing breeding ritual, where a male and female pass a berry back and forth, strengthening the bond between the pair. If you want waxwings in your garden, trying growing shrubs and trees with berries – rowan and guelder rose work particularly well.



FIELDFARE

These large thrushes visit the UK every winter, to escape the harsher Scandinavian weather. They usually feed on berries and other fruit, or worms if the ground is soft enough. Last year they flocked to UK gardens in large numbers during the 'Beast from the East', because their natural food sources had run out or weren't accessible during the chilly weather. When temperatures plunge, you can help them by putting broken-up apples or pears on your lawn.



STARLING

Like goldcrests, starlings are native to the UK, but their numbers are boosted in the winter by warmth-seeking visitors from Scandinavia. Starlings are excellent mimics, copying the calls of other birds, as well as sirens and mobile phone ringtones. You can attract starlings to your garden by keeping your lawn short and chemical-free, which allows the birds to safely poke around for leatherjackets (cranefly larvae) – their favourite food.

02

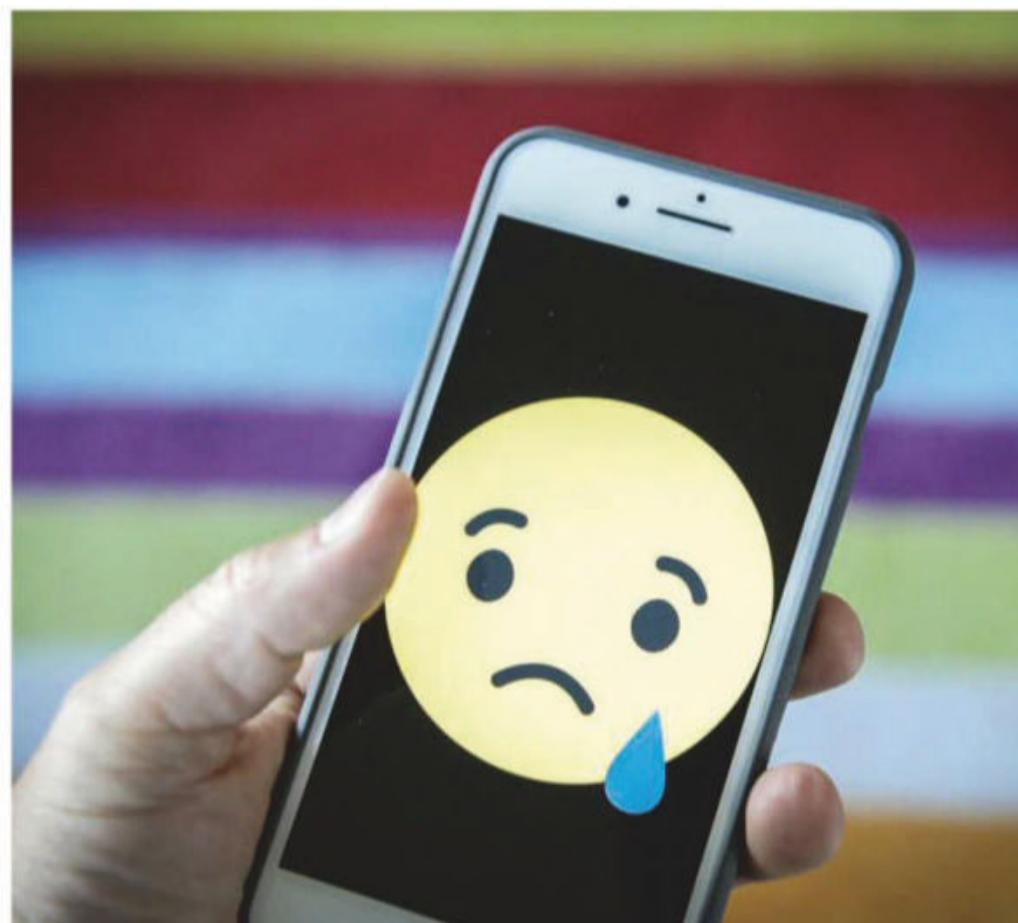
AN EVENING OF UNNECESSARY DETAILBACKYARD COMEDY CLUB, LONDON
29 JANUARY 2019, 7:30PM
FESTIVALOFTHESPOKENNERD.COM

LAUGH AT THE LITTLE THINGS

For a good, geeky laugh, get yourself along to this evening of live and exceptionally nerdy comedy. A team of scientists/stand-up comedians will ask enthusiasts, researchers, miscellaneous experts and funny people to talk about whatever they want, in as much detail as they'd like.

The trio of hosts includes Helen Arney, a physics graduate from Imperial College London who writes songs inspired by

science; Matt Parker, who's had a sell-out comedy show at Edinburgh Fringe while also being a university maths lecturer; and Steve Mould, the science presenter on *Blue Peter* "back in the day".



03

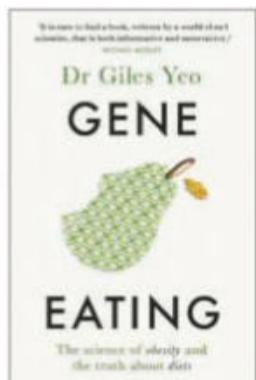
MENTAL HEALTH IN A DIGITAL AGEROYAL INSTITUTION, LONDON
15 JANUARY 2019, 7PM
RIGB.ORG

TACKLE MENTAL HEALTH WITH TECH

Though some argue that new technology might be partly to blame for modern mental health issues, it could also act as a cure. The Royal Institution is bringing together three experts to discuss how medicine, science and technology can address this ever more pressing problem for modern society. They'll discuss the digital innovations that could help those with mental health issues, find out how to increase public access to new technology, and look at a specific platform that's transforming mood monitoring in bipolar patients.

04

GENE EATING
DR GILES YEO
 OUT NOW
 (£14.99, SEVEN DIALS)



Dr Giles Yeo is a Cambridge based geneticist, and presenter on BBC Two's *Trust Me, I'm A Doctor*.

EAT FOR YOUR GENES

Geneticist DR GILES YEO argues that biology, rather than self-discipline, is to blame for the obesity crisis. He talks to HELEN GLENNY about his new book and what we need to understand in order to tackle the obesity epidemic and improve our health

How do our bodies regulate our weight?

The brain controls our food intake, and for that it needs to know how much fat we have onboard. Fat releases hormones, and our brains monitor those hormones to figure out how much fat we have. Our brains also need to know what we've just eaten, and what we're currently eating. That's obtained from hormones from the stomach and the gut. The brain integrates this information to decide what, and how much, to eat.

What effects do our genes have?

Simply put, there are some people whose brains are slightly less sensitive to the signals coming from the gut and from fat. If that's you, your brain thinks you have slightly less fat than you actually do, or thinks you've eaten slightly less than you actually have. And if it's slightly less sensitive you're going to eat a little more. Those differences are subtle. You're not going to eat 10 times as much, you're just going to eat a few percentage points more. You may only feel a tiny bit more hungry,

but you feel that all of the time. Over a lifetime, you gain weight.

It's still about food intake. We get fat because we eat more than we burn. But where the biological variation lies is in some people being more hungry than others, and that explains why some people eat more than others.

Why is being fat bad for us?

Your fat is the safest place to store excess energy – that's its role. When people become fat, they don't get more fat cells, they get bigger fat cells. Imagine a balloon. When you get fatter the balloon swells up, and when you burn energy the balloon gets smaller. That is how gaining and losing weight works. But at some point the balloon gets too full. Then the fat has to go somewhere else, and it's when it goes somewhere where it's not supposed to be, like your muscles or liver, that you begin to tilt into metabolic disease [diabetes, obesity and high blood pressure].

But do everyone's fat cells expand to the same size? The answer, which we've only discovered recently, is no.

Everyone has a 'safe' fat-carrying capacity, in terms of how big the balloon can get, but the size of the balloon is going to differ from person to person. You can get skinny people with type 2 diabetes, and on the other extreme, you get 300-400lb people who have to get craned out of their houses by the fire service. But these people are rare, because the vast majority of us would have died already of type 2 diabetes or cardiovascular disease before we got to that size.

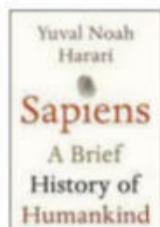
It's all about your personal fat-carrying capacity. And how do we tell what that is for each person? It's difficult. We don't know yet.

Will we ever get to a point where we can change our genes?

Ethics aside, let's assume that society has come to accept gene editing. Then it all comes down to what you're trying to change. The problem with obesity is that it's regulated by hundreds of genes, and we only have the technology to change one gene. I don't think being able to change something this complex is going to be possible in the foreseeable future.

AUTHOR'S BOOKSHELF

Three books that inspired Giles while he was writing *Gene Eating*



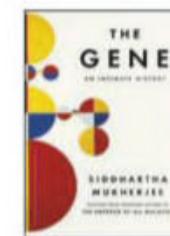
SAPIENS
BY YUVAL NOAH HARARI
 (£9.99, VINTAGE PUBLISHING)

This book is a wonderful brief history of humankind. A tour de force. I took a lot of inspiration from this book when charting our dietary history.



THINKING, FAST AND SLOW
BY DANIEL KAHNEMAN
 (£10.99, PENGUIN)

This book, by economist Kahneman, offered me inspiration when reflecting on why some are so willing to believe what to others is obviously false.



THE GENE: AN INTIMATE HISTORY
BY SIDDHARTHA MUKHERJEE
 (£10.99, VINTAGE)

A wonderful history of the gene. As a geneticist, I am biased of course!

05

CHEMISTS' DIRTY SECRET

BBC RADIO 4

12 JANUARY 2019, 8PM

EXPLORE THE SECRET SIDE OF CHEMISTRY

From chlorine gas deployed in WWI by the German military, to the Novichok nerve agent used to target former Soviet agent Sergei Skripal in the UK, chemical weapons have long been used to terrorise soldiers and civilians. Prof Andrea Sella, a chemist at University College London, is concerned about the role of his profession in developing these weapons. In this Radio 4 programme, he investigates the ongoing campaign to control the use of the weapons, and asks how science educators can prepare young chemists for the moral hazards they could encounter in this important profession.



06

SPACE LATES – DEEP SPACE

NATIONAL SPACE CENTRE, LEICESTER

12 JANUARY 2019, 6PM

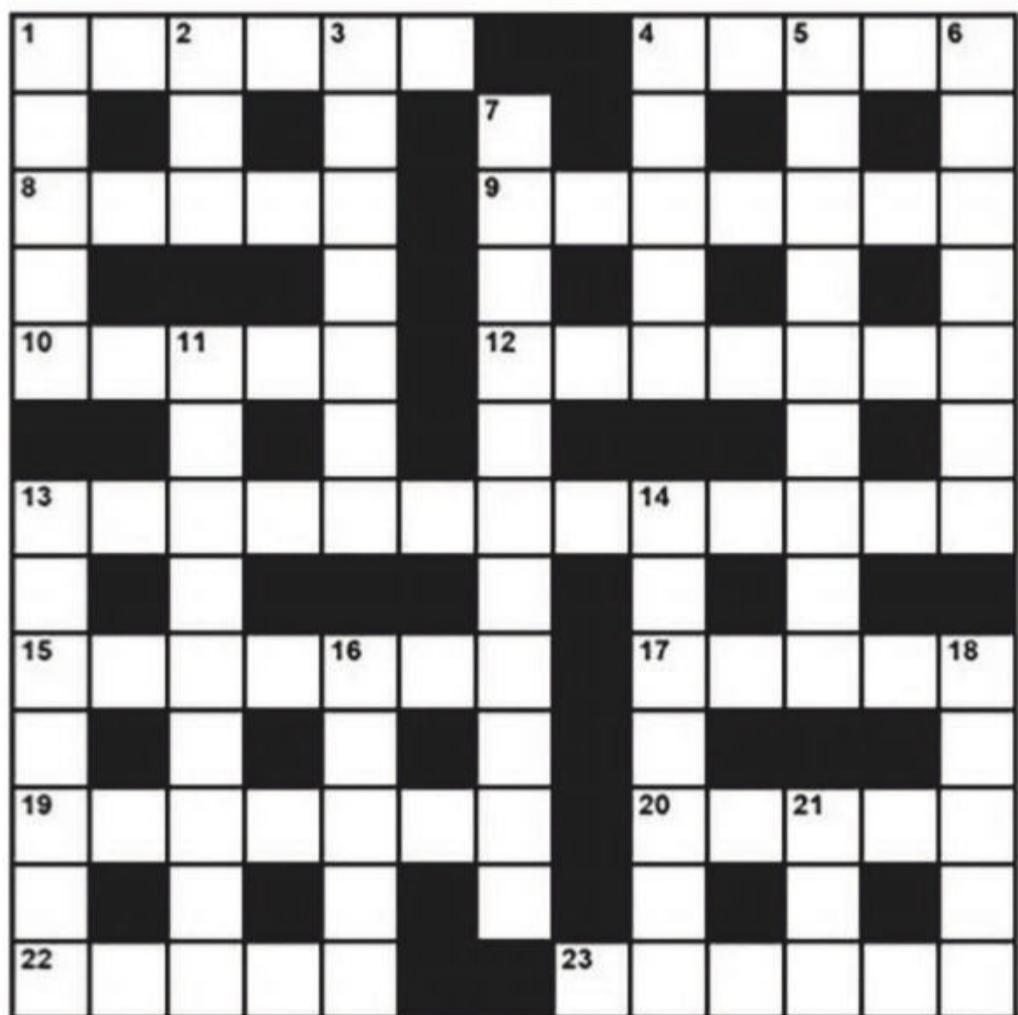
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BBC FOCUS CROSSWORD

GIVE YOUR BRAIN A WORKOUT



ACROSS

- Pet puts old grass on old china (6)
- Reverse surgery on youngster in temporary location (3-2)
- Rota organised by a vital supplier (5)
- Destructive force has split a party (7)
- Article, thanks to foreign character (5)
- Thwart fellow leaving healthy fuel supplier (3,4)
- Medium colours show range of frequencies (5,8)
- Initially broadcast one series on transport (7)
- An ape bursting into song (5)
- Journey round large island capital (7)
- His second boy inspires writer's third poem (5)
- Bay and chestnut start to smell (5)
- Energy for every vegetable (6)

DOWN

- Credit back in pursuit (5)
- Foment a row with a sailor (3)
- Native American has a knock and a laugh (7)
- Supernatural being left in danger (5)
- Earth, say, about European feature of London (5,4)
- Difficulty parking, more chaotic around British lake (7)
- Pressure at sea level having a romantic mood (11)
- Conclusion, awful or nice, in some glands (9)
- Unemotional chap relating to listeners (7)
- Overturn magnitude of headwear (7)
- Notice grandfather, for one (5)
- Lowest point of drain layout (5)
- I am putting pressure on monkey (3)

CARNEGIE INSTITUTE FOR SCIENCE, GETTY IMAGES X3

ANSWERS

For the answers, visit bit.ly/BBCFocusCW
Please be aware the website address is case-sensitive.

NEXT MONTH IN

FOCUS

THE FAR SIDE OF THE MOON

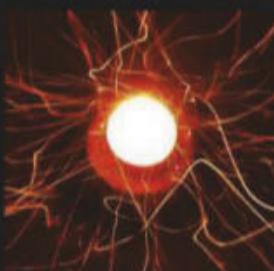
INSIDE CHINA'S MISSION TO
BUILD A LUNAR BASE



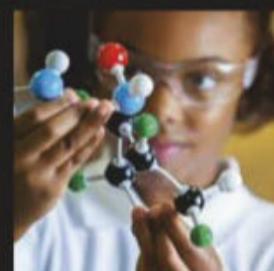
ON SALE
6 FEBRUARY
2019

PLUS

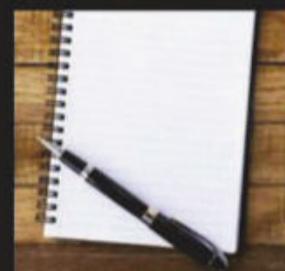
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Girls and science



Living with no imagination



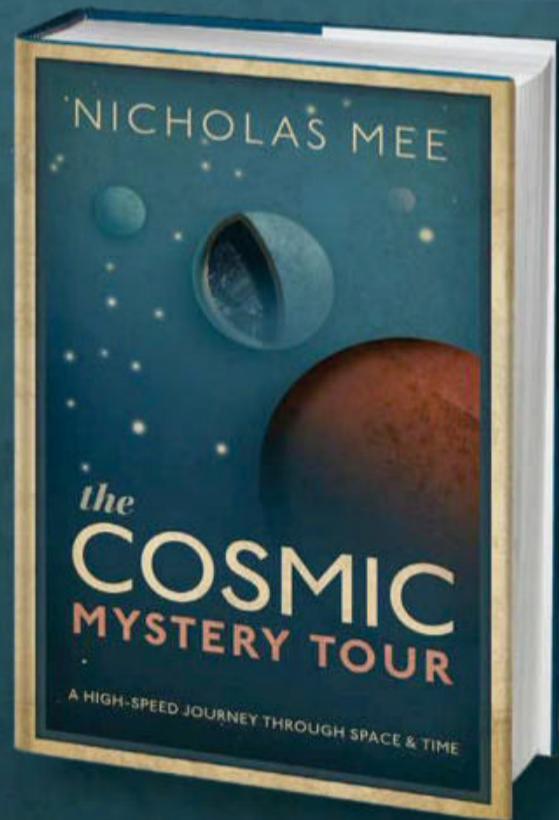
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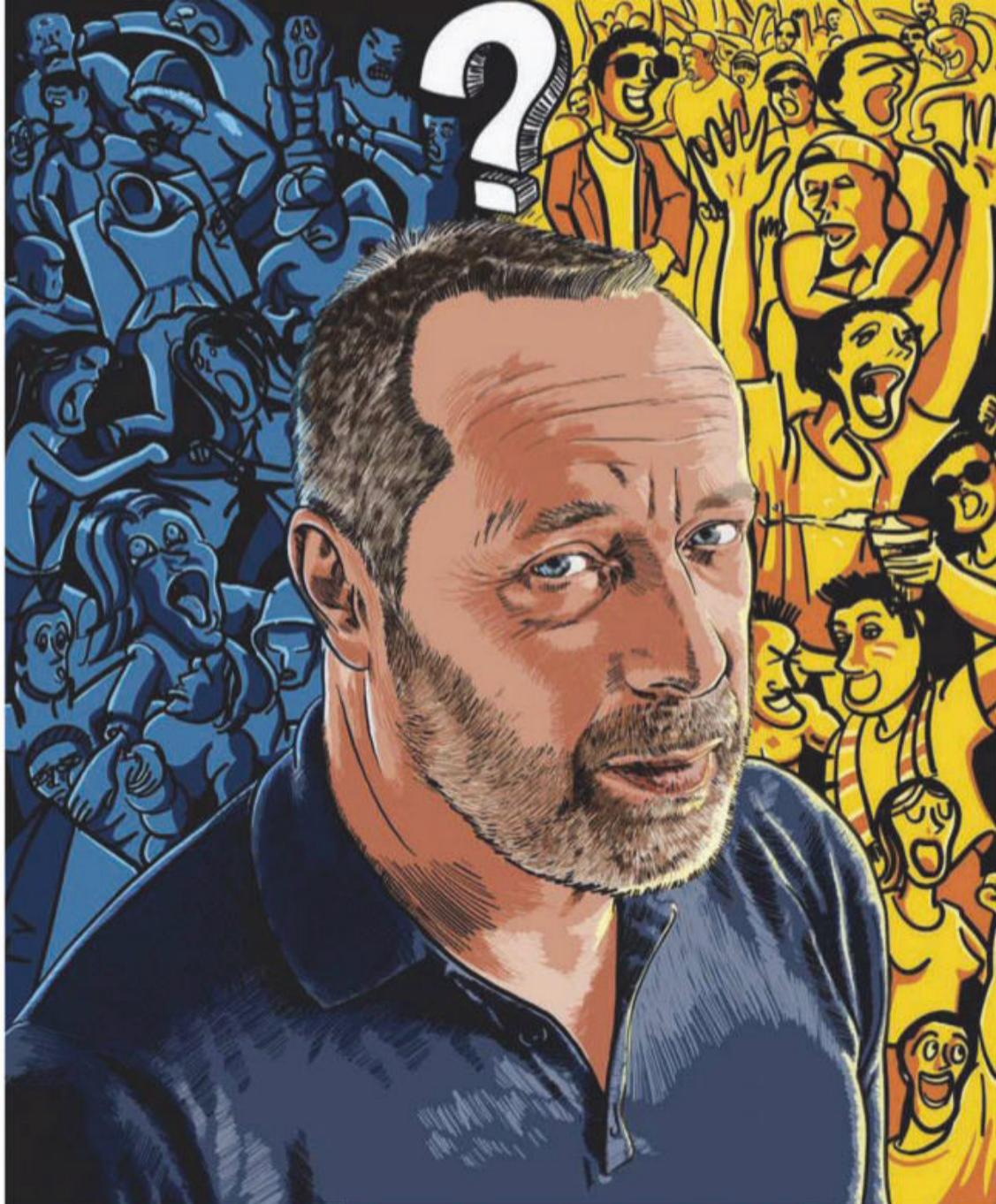
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MY LIFE SCIENTIFIC

Prof Stephen Reicher

Thinking of heading off to the January sales? Think again. Psychologist **Stephen Reicher** tells **Helen Pilcher** about the pleasure and perils of being part of a crowd

The Prayag Magh Mela, discussed here by Stephen, is a holy Hindu fair. It is next scheduled to take place in 2025.

How did you become interested in the study of crowds?

When I studied, psychology was influenced by the Holocaust. It still is. My family is Jewish. My father fled Poland. Suddenly, questions of how we behave in groups stopped being an intellectual exercise and started to be something that mattered. It came alive for me.

Does a 'mob mentality' really exist?

For a long time, crowds were viewed as predominantly negative, as you lose your identity, morality and sense of control. But what we've

found is the opposite. People don't lose their identity. They shift to a *shared* identity where values and goals of the group are prioritised. Certain groups – like the Nazis – have toxic values and goals, so Nazi crowds are toxic. But shared identity can lead to intimacy, respect and support, and provides the basis for people to work together. It can be incredibly empowering.

Power to the people!

Exactly! The civil rights movement challenged racism. The women's movement challenged sexism. Stonewall challenged

discrimination against gay people. Crowds enable disadvantaged individuals to challenge injustice. People tell you that some of the most meaningful moments in their lives were as part of a crowd when they felt they were making a difference.

How? I felt unwell when I rode a tube with my face in a man's armpit...

We've studied people attending the world's biggest pilgrimage, Prayag Magh Mela, where up to 100 million people come together once every 12 years. It's noisy and crowded, with only a rudimentary sewage system, yet people talk about serenity and bliss. There's a sense of control and connection, which decreases stress levels. We've found that it's good for mental and physical health.

So why do I find the January sales so traumatic?

Because there are different types of crowd. In psychological crowds, we feel this shared sense of purpose. In physical crowds, we have no sense of connection. Sales crowds are physical crowds. No one likes being crushed up next to people they have no connection with.

Do you like the sales?

They are awful. We did a virtual reality simulation of a fire at King's Cross underground station. We told some people they were coming back from a music concert, and others they were returning from shopping at the sales. The concert-goers helped one another and escaped more quickly, compared to the shoppers who didn't work together and were less efficient at escaping. Consumerisation sets us up against one another, so everyone is potential competition. I go to great lengths to avoid physical crowds.

So avoid the physical crowds but embrace the psychological ones?

Exactly. 

Prof Stephen Reicher is a social psychologist at the University of St Andrews.

[DISCOVER MORE](#)



To listen to an episode of *The Life Scientific* with Prof Stephen Reicher, visit bit.ly/steve_reicher

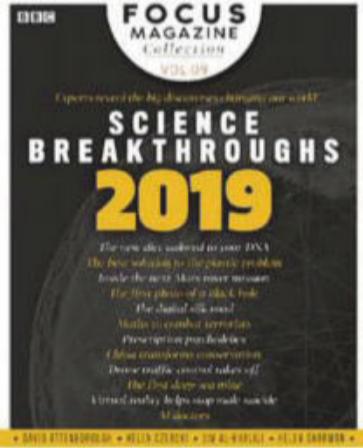
NEXT ISSUE: MELANIE WINDRIDGE

"IT'S NOISY AND CROWDED, WITH A RUDIMENTARY SEWAGE SYSTEM, YET PEOPLE TALK ABOUT SERENITY"

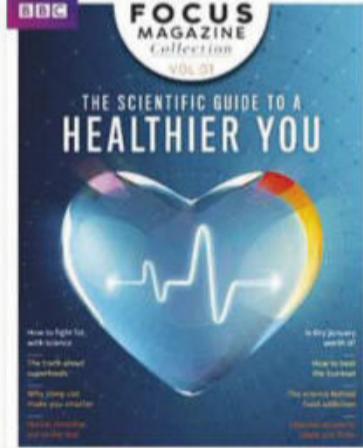
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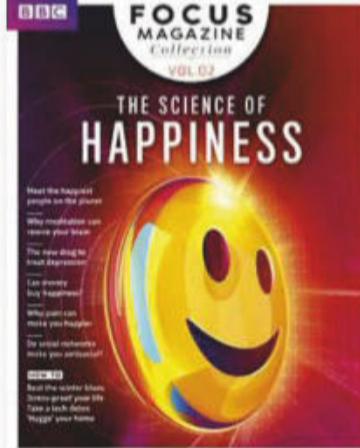
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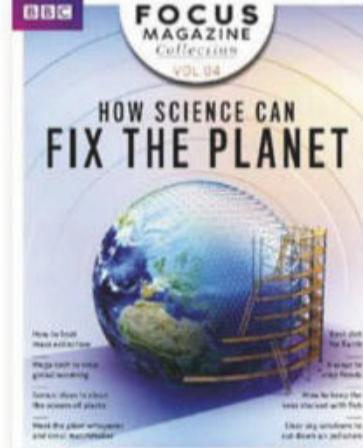
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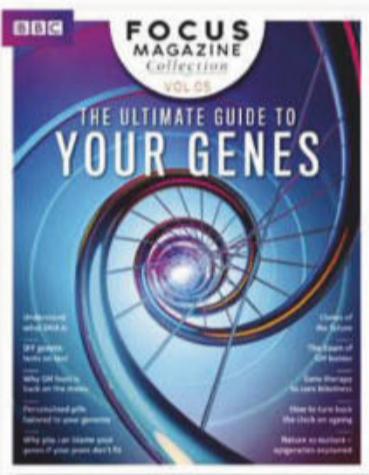
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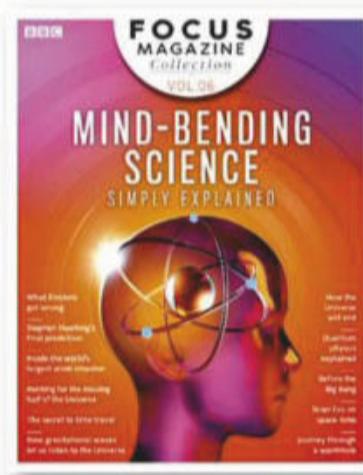
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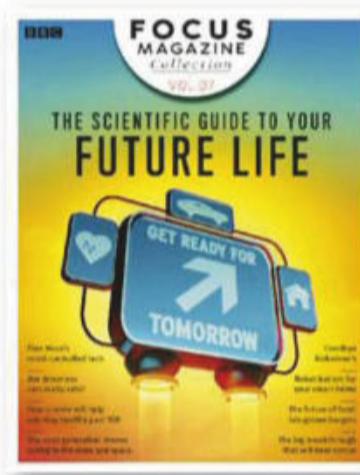
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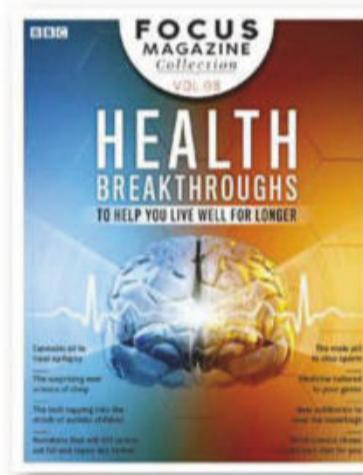
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